2040
Strategic Water Supply Plan

Norman Utilities Authority

CDM

Camp Dresser & McKee Inc.

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Executive Summary

The City of Norman, Oklahoma, (City) has historically enjoyed an adequate supply of water to support the community. However, the City's annual water demand is fast approaching the annual yield potential of the existing water resources. More acutely, summertime daily demands have exceeded the City's water production facilities several times over the last decade. This has been evidenced by periods of rationing during summer months.

To not only meet this ever-increasing demand, but also to stay ahead of it in the future, the City is faced with the difficult task of securing additional and plentiful water supply. Several water supply sources are available to the City. Each water resource will, to some degree, require infrastructure (storage, pipelines, pumps, treatment facilities, etc.) necessary for conveyance, treatment, and production.

This 2040 Strategic Water Supply Plan (Plan) was initiated to develop a guidance tool for best positioning the City to secure additional water resources and plan for associated infrastructure needs that will satisfy water demand into the future. Development of this Plan involved close coordination with City staff, officials, and citizens through workshops and public forums to assure the development of a realistic and representative approach to planning for the City's future water supply needs. This Plan includes the following sections.

- Executive Summary
- Baseline Development
- Existing System Assessment
- Alternatives Evaluation
- Plan Development

Baseline Development

The first step in preparing this Plan involved developing projections for the City's water demand over the next 40 years, which is the basis for water resource and production needs, and is termed as the baseline. Development of the baseline allows the City to identify how much water resources annual yield and production capacity will be needed in the future to secure safe, reliable, and abundant drinking water for the citizens of Norman.

The City's water demand is proportional to the population served. Hence, population projections for the planning horizon were developed in order to create a water demand baseline. The population growth rates for the next 40 years are comparable to growth trends during the 1980s and 1990s. For the planning horizon, it is anticipated that the City will grow from a 1999 population of 94,527 to a 2040 population of 157,598.

In addition to determining population projections, a sensitivity analysis was also conducted for appropriate development of the projected water demand baselines. Different factors influence the quantity of water a city demands over the course of many years. Demand sensitivity factors include weather patterns, outside customers, water use restrictions or rationing, cost-of-water rate structures, per capita consumption, and conservation measures. As such, the City must plan for the demand variables to properly provide for its service population when such conditions arise.

The sensitivity factors discussed above were used to evaluate water demands over the 40-year planning horizon to develop the baseline. Two baseline sensitivity bands were developed to describe Norman's water needs: 1) annual-average daily flow, and 2) maximum-daily flow. Annual-average daily flow is the amount of water the City typically requires on a daily basis over the course of a year. This amount dictates how much annual water supply the City's water resources must yield. Maximum-daily flow is the amount of water the City might use during a high-demand day, but does not represent everyday typical demand. This amount dictates the finished water production capacity the City of Norman must be able to produce for its service population. The developed sensitivity bands are presented on Figures ES-1 and ES-2.

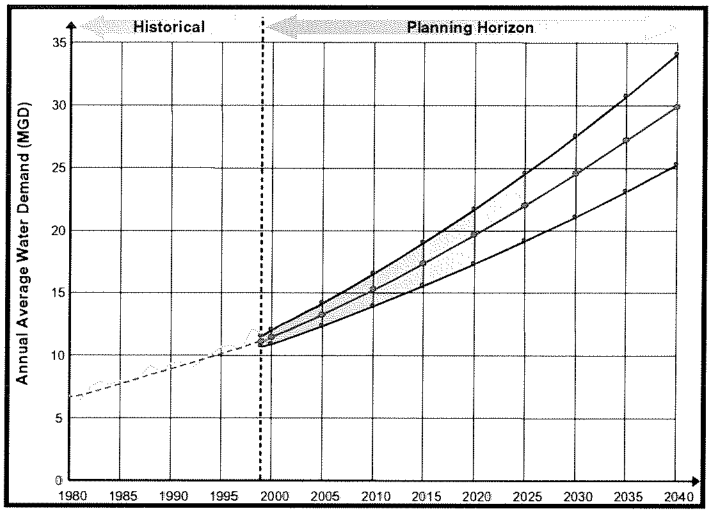


FIGURE ES-1
Annual-Average Water Demands

Figure ES-1 illustrates the annual-average water demand projections for the years 2000 through 2040. The range in demand indicates the difference between high and low demand years. The projected baseline indicates that the annual-average water demand could range between 25 and 34 mgd in 2040.

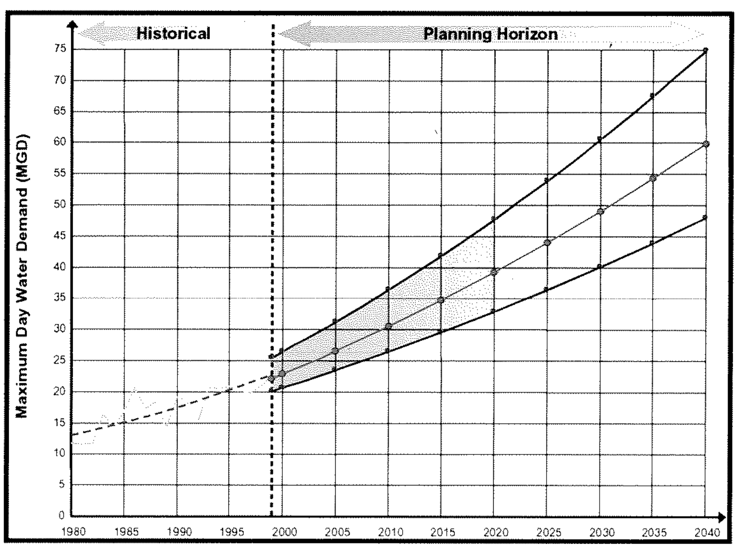


Figure ES-2 illustrates the maximum-day water demand projections for the years 2000 through 2040. As before, the range in demand indicates the difference between high- and low-demand days during a given year. The projected baseline indicates that the maximum-day water demand could range between 48 and 75 mgd in 2040.

FIGURE ES-2
Maximum-Day Water Demands

Following development of water demand projections, the City of Norman's current water supply system was assessed in order to determine the amount of additional water supply would be required over the planning horizon. The following section summarizes the City's existing water supply resources and production system.

Existing System Assessment

The City of Norman benefits from two water supply sources—surface water yield from Lake Thunderbird and groundwater yield from the Garber-Wellington Aquifer. The City is allocated an annual-average yield of 8.4 mgd from Lake Thunderbird under its current contract, but can treat up to 14 mgd at the water treatment plant (WTP), which is the maximum amount of raw water the conveyance system can transport from Lake Thunderbird to the WTP. The City has exceeded its 8.4-mgd allocation five times in the past nine years, suggesting that the increased population and demand is having a taxing effect on the system.

The City currently uses Lake Thunderbird to supply approximately 70 percent of the average-annual demand. The remaining 30 percent of the water is supplied from groundwater wells pumping from the Garber-Wellington Aquifer. An array of 31 city-owned deep wells tap the Garber-Wellington Aquifer and can supply an average 4.2 mgd. However, for short durations, and during high-demand periods, the wells can provide 8.1 mgd. Based on the water demand normalized projections and on the water resources currently available to the City of Norman, typical year additional water resource capacity and required production capacity are illustrated on Figures ES-3 and ES-4.

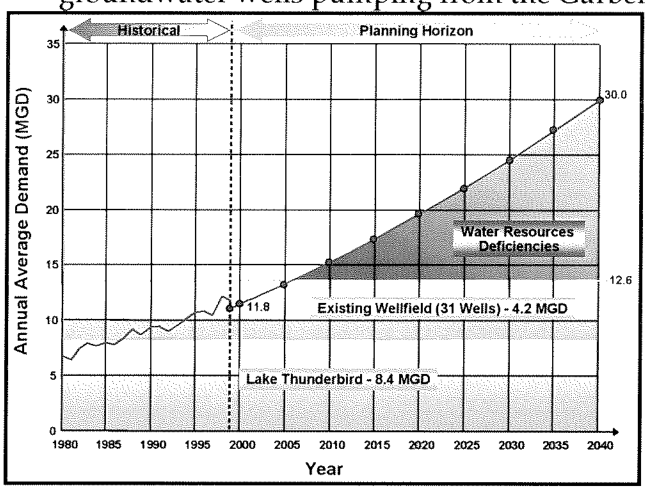
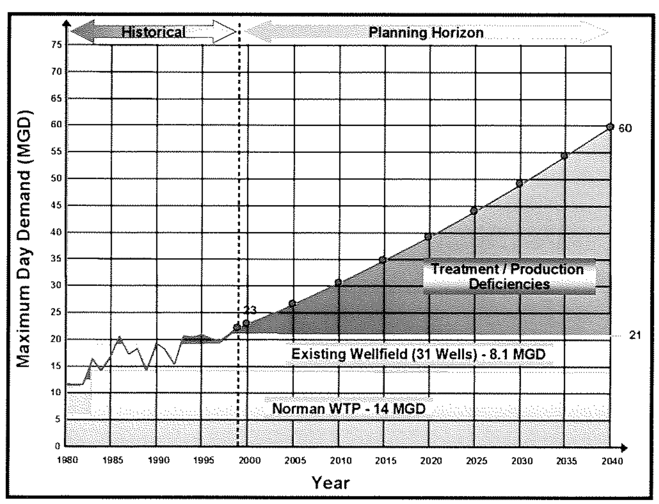


FIGURE ES-3
Water Resources Deficiencies

Figure ES-3 illustrates the normalized annual-average demand over the planning horizon relative to current water resources yield. The red highlighted area represents the projected water resources deficiency through Year 2040.

Similarly, Figure ES-4 illustrates the normalized maximum-day demand over the planning horizon relative to current system production capacities. The red highlighted area represents the projected production deficiency through 2040.

FIGURE ES-4
Water Production Deficiencies



A cornerstone objective of this Plan was to not only develop the approach for satisfying planning horizon water demands, but to stay ahead of demand. When a City determines that additional water resources are needed, the process of developing the additional resource(s) can range up to 10 to 20 years (or even longer) depending on the type of resource, location with respect to the service population, obtaining rights to the resource, land acquisition, and constructing the required infrastructure for conveyance. As stated previously, the raw water resource supply required by the City is related to the annual-average water demand. Hence, when planning for annual-average demand, it is advised that the City of Norman plan for a minimum of 20 years ahead of the normalized annual-average demand baseline. Without such planning capacity incorporated into the Plan, Norman would be able to satisfy only the demand required for a typical current year, but would be under-developed for the following years. The following figures illustrate the projected planning capacity for water resources.

Figure ES-5 illustrates the 20-year implementation window for development of additional water resources to satisfy normalized annual-average water demands. To plan for Year 2040, Norman should secure 30 mgd in additional water rights over current.

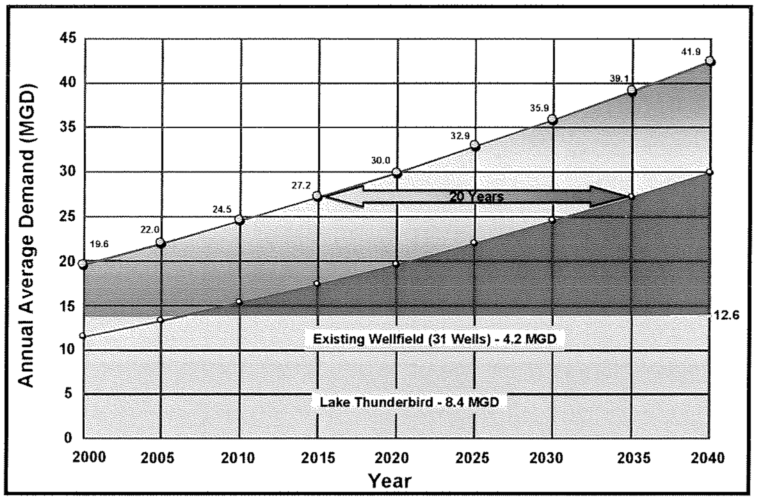


FIGURE ES-5
Planning Capacity: Water Resources

Unlike the implementation window required for the development of additional water resources, the implementation window required for development of additional production infrastructure, such as a water treatment plant expansion, requires a typical duration of five years. Therefore, adopting a water production planning capacity with a five-year allowance for implementation is recommended. Figure ES-6 illustrates the projected planning capacity curve for water production.

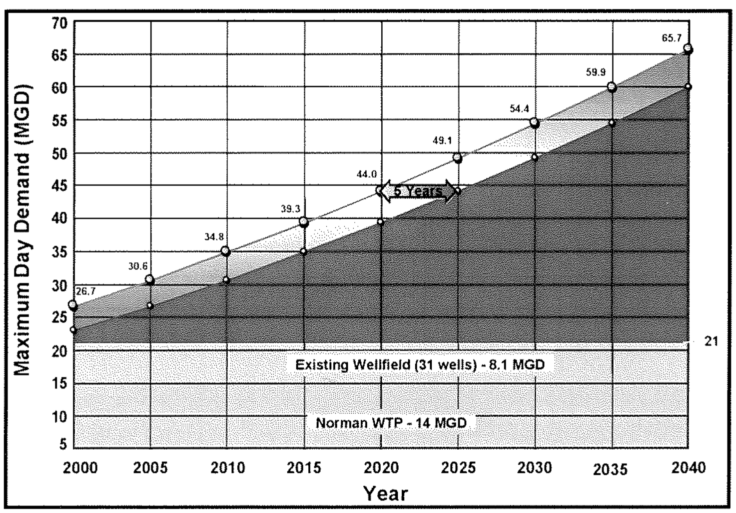


Figure ES-6 illustrates the 5-year implementation window for development of additional production capacity to satisfy normalized maximum-day demands. To plan for Year 2040, Norman will require an additional production capacity of 44 mgd over current.

FIGURE ES-6
Planning Capacity: Production

As shown on Figures ES-5 and ES-6, the City of Norman is faced with developing additional water resources that are both reliable and plentiful in order to plan for the future water demands of the citizens. For the Plan, an additional 30 mgd of water resource capacity and an additional 44 mgd of production capacity was targeted.

Alternatives Evaluation

Water Resource Alternatives

In a long-list, 17 possible water resource alternatives were identified as candidates for meeting Plan water resources and production targets. Each of the considered alternatives was evaluated and characterized based on water quality, location, water storage capacity, available water yield, cost associated with securing the water supply, policy issues, and likelihood of development. The alternatives evaluated are listed below.

TABLE ES-1
Water Resource Alternatives

Additional Lake Thunderbird Under Utilized COMCD Allocation	Additional Lake Thunderbird Flood Control Pool
OKC Treated Water Purchase (Base Supply)	Expanded Garber-Wellington Wellfield
OKC Treated Water Purchase (Peak Supply)	Hugo Reservoir
	Sardis Reservoir
OKC Raw Water Purchase	Kiamichi River
Arbuckle Simpson Aquifer	Planned Parker Reservoir
Canadian Terrace Deposits	McGee Creek Reservoir
Canadian Alluvial Deposits	Indirect Potable Reuse
South Canadian River	Direct Nonpotable Reuse

Based on the results of the evaluation and input from the City, each long-list water resource alternative was either short-listed or discounted according to the following factors.

- Water quality
- Potential yield
- Timing for development
- Feasibility of development
- Unresolved policy issues
- City of Norman Strategic Water Supply Policy
- Discussion with City staff, officials, and citizens
- Findings in previous reports and studies

Six water supply alternatives that offer the greatest potential and most cost-effective means for securing safe and reliable supply to meet the City's projected water demands through the planning horizon were chosen from the long-list. The six short-listed options are:

- Additional Lake Thunderbird (unused conservation and flood pools)
- New Garber-Wellington Wellfield
- Hugo Reservoir (Southeast Oklahoma)
- South Canadian River
- Oklahoma City Treated
- Oklahoma City Raw (Southeast Oklahoma)

Conceptual development of each short-listed alternative was conducted. This included identification of infrastructure required for conveyance, raw water storage, treatment, and production. Furthermore, conceptual costs were identified for each short-list water resource alternative.

Plan Alternatives

The six short-listed water resources alternatives were assembled to create six different Strategic Water Supply Plan Alternatives to meet the planning horizon capacity targets. Since no single water resource was considered a panacea for the entire 40-year planning horizon, short-, medium-, and long-term needs were identified in order to assemble the Plan Alternatives.

Figure ES-7 represents the target planning capacity for securing additional water resources. As illustrated, short-, mid-, and long-term goals are 22, 30, and 41.9 mgd, respectively. With the City's current resources totaling 12.6 mgd, an additional supply of approximately 10, 18, and 30 mgd, respectively, was targeted.

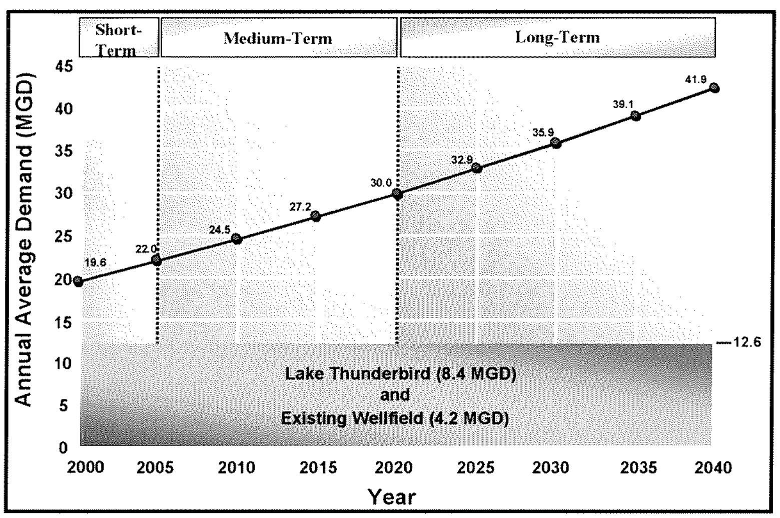


FIGURE ES-7
Resource Target Capacity

The six Plan Alternatives, comprised of various combinations of the short-listed water resource alternatives, are summarized and presented on Figures ES-8 through ES-13. The basis for creating these plans was to first utilize the City's existing water supply resources (Lake Thunderbird and the Garber-Wellington Aquifer), then expand the City's groundwater supply source, and follow with additional surface water supply sources.

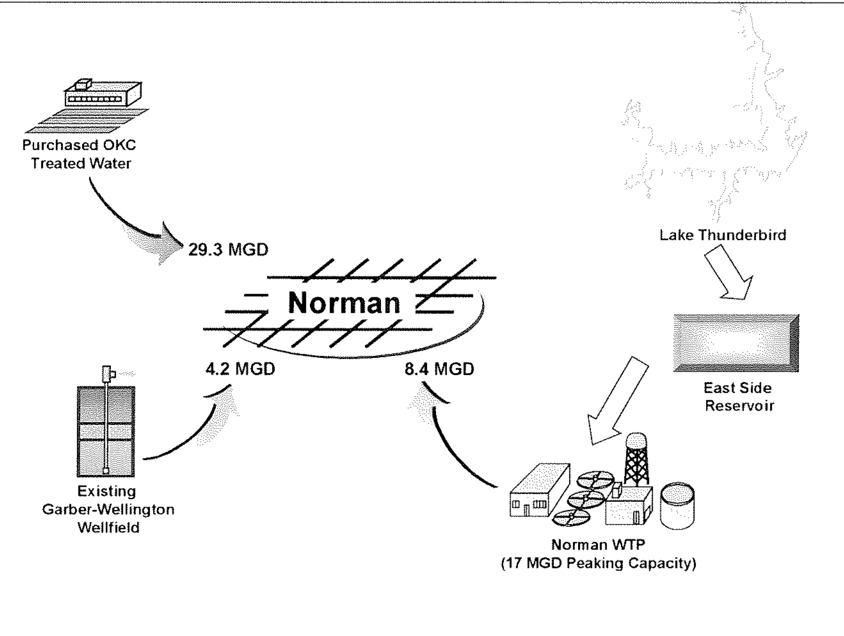


FIGURE ES-8
Plan A - Do-Nothing Alternative

- Sources of supply include the existing wellfield, Lake Thunderbird, and Oklahoma City-treated.
- Existing resources are maintained at current capacity.
- Purchase of treated water from OKC is required to satisfy the majority portion of the demand.

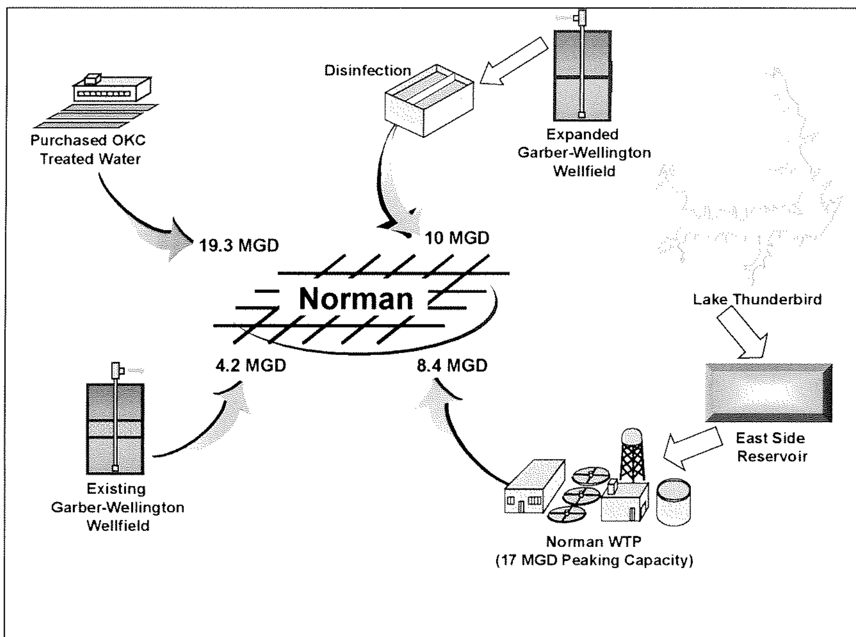


FIGURE ES-9
Plan B - Garber-Wellington Aquifer Alternative

- Sources of supply include the existing wellfield, Lake Thunderbird, new wellfield, and OKC treated.
- This alternative includes the development of an expanded wellfield and reduced purchase of treated water from Oklahoma City.

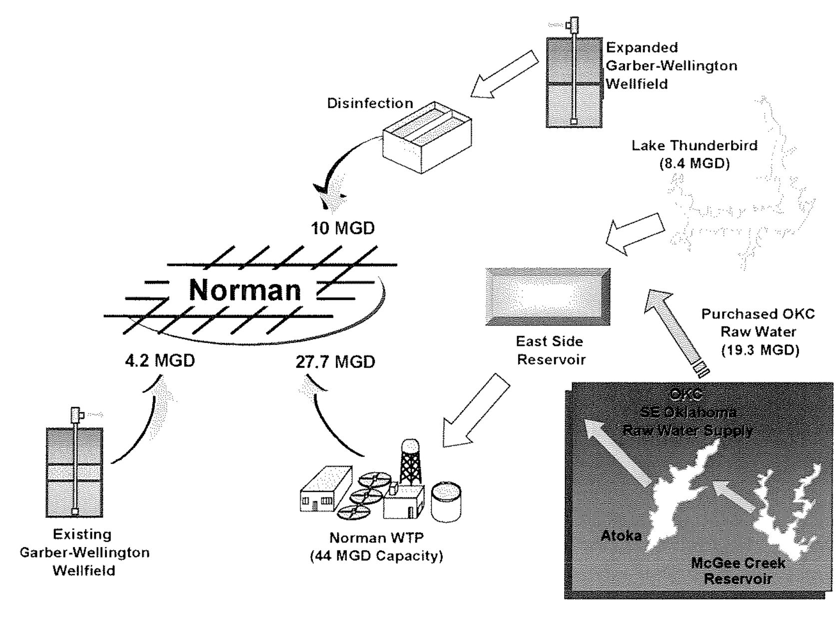


FIGURE ES-10
Plan C - Southeast Oklahoma Alternative

- Supply sources include same as those for Plan B; however, the City would transition to raw water purchase from OKC in the mid-term.
- This alternative would maintain the City's position as a partner for future use of high quality supply from sources emerging in Southeast Oklahoma.

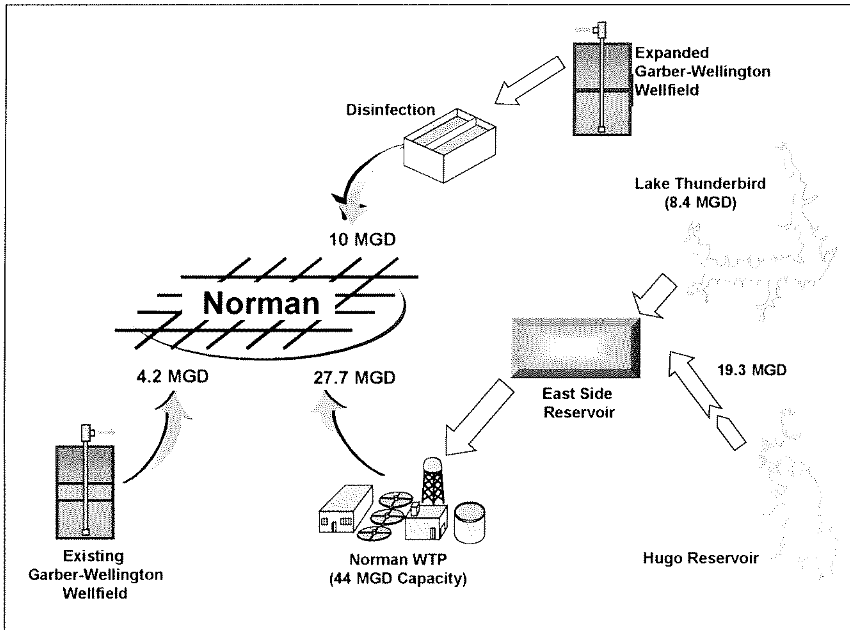


FIGURE ES-11
Plan D - Hugo Reservoir Alternative

- Sources of supply are similar to those under Plan C, differing with respect to transition to Hugo Reservoir for long-term raw water supply.

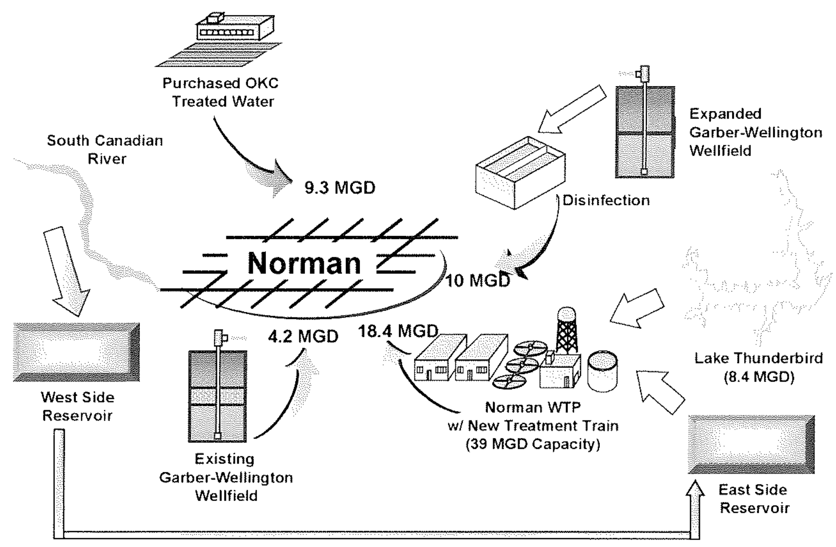


FIGURE ES-12
Plan E - South Canadian Two Reservoirs Alternative

- Sources of supply include the existing wellfield, Lake Thunderbird, expanded wellfield, and South Canadian River.
- Supply from the South Canadian would be utilized to support two reservoirs, and hence, one WTP facility for the Lake Thunderbird and South Canadian River supplies.
- Purchase of OKC treated water is needed in the long term.

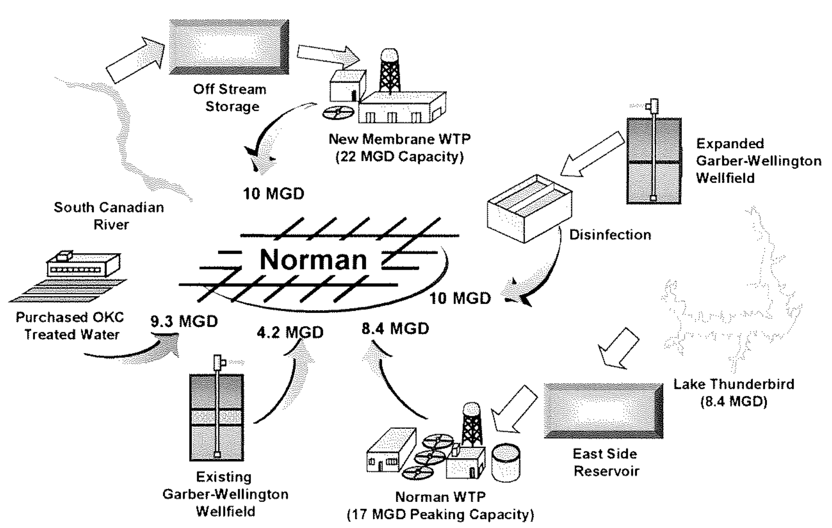


FIGURE ES-13
Plan F - South Canadian One Reservoir Alternative

- Sources of supply are similar to those under Plan E, differing with respect to implementation of one South Canadian Reservoir and a new Westside WTP dedicated to the raw water supply from the river.
- Purchase of OKC treated water is needed in the long term.

For the six Plan Alternatives presented above, an evaluation of each plan was conducted based on monetary and non-monetary factors. The results of each plan's evaluation were compared and ranked in order to select the best available plan to meet the City of Norman's planning horizon goals. Compilations of monetary and non-monetary factors as well as plan evaluations are discussed in the following paragraphs.

Monetary evaluation of the plan alternatives involved comparison of capital costs, annual O&M costs, and a 40-Year total present worth. The monetary rankings are presented in Table ES-2.

Plan Alternative	A	B	C	D	E	F
Final Ranking	6	1	2.5	4.5	2.5	4.5

Ranking: 1 = Most Favorable ; 6 = Least Favorable

TABLE ES-2
Final Monetary Ranking Results

On a monetary basis, Plan B ranked as the best alternative followed, in order, by Plans C, E, F, D, and A. However, monetary factors are not the only variables influencing the selection of the best-suited plan for the City of Norman. Using input from City staff, City officials, and citizens, a series of non-monetary factors were identified. The following factors were considered during the non-monetary evaluation.

- Public acceptance
- Water quality and compatibility
- Water rights
- Environmental impacts
- Reliability
- Implementability
- Future implications
- Flexibility
- Redundancy

Table ES-3 provides the results of the non-monetary evaluation.

Plan Alternative	A	B	C	D	E	F
Final Ranking	6	5	1	2	3	4

Ranking: 1 = Most Favorable ; 6 = Least Favorable

TABLE ES-3
Non-Monetary Ranking Results

Based on non-monetary ranking, Plan C, which was second place in monetary ranking, ranks first. Plan B, which was ranked first in monetary ranking, ranks fifth in the non-monetary ranking evaluation.

Selection of Plan A would require the City of Norman to rely heavily on the City of Oklahoma City (OKC) as a major source of water supply. Such reliance would greatly reduce the City's negotiating leverage in the future, and limit the potential to develop a more cost-effective water supply source in the future through sole initiation or partnerships. Choosing Plan A would place the City of Norman's water system under the indirect control of OKC. When OKC raises water rates or varies rate structures, the City of Norman would have no other choice but to pass those levies to the citizens. As a result, Plan A ranks last in non-monetary ranking.

Plan B maximizes the use of the City's most cost-effective water supply source (Garber-Wellington Aquifer) to decrease reliance on OKC purchased water. However, this plan assumes the same potential flaw (relying heavily on OKC treated water) as Plan A and ranks fifth based on non-monetary factors. Again, heavy reliance on purchased treated water from OKC in the long term greatly reduces the City's latitude in gaining ownership of a new and potentially more cost-effective water supply sources in the future.

Plan C couples the expanded wellfield with an additional surface water resource—OKC raw water from Southeast Oklahoma via Atoka and McGee Creek Reservoirs. With Plan C, the City retains control of its water supply future. Water supply system components, including capacity, replacement, and quality, remain under the control of the City of Norman. Of the six plans, Plan C ranks second monetarily and first non-monetarily. Such favorable rankings are largely due to this plan taking full advantage of the City's existing resources and infrastructure to meet the water demands, while best positioning the City to potentially acquire ownership of emerging regional plans to develop resources in the Kiamichi River Basin (i.e., Sardis, Kiamichi River, and Hugo) of Southeast Oklahoma. Such ownership would meet the City of Norman's needs well beyond the 40-year planning horizon of this Strategic Water Supply Plan.

Plan D incorporates similar capital projects included in Plan C. However, the City would transition from Southeast OKC raw water supply to Hugo Reservoir in the long term. Plan D has the second highest total present worth (ranking fifth monetarily), with raw water conveyance infrastructure from Southeast Oklahoma to Norman being a major cost component. However, this is the only plan of the six that provides the City with full ownership of resources that exceed the Year 2040 water demands. Thus, Plan D ranks second non-monetarily.

Plan E and F include development of the South Canadian River with appropriately sized off-stream storage reservoirs and treatment facilities. Plan E includes capturing and conveying raw water supply from the South Canadian River to a west-side terminal reservoir when river flows are sufficient to support the practice. Raw water from the west-side reservoir would be conveyed to an east-side reservoir in close proximity to the existing Norman WTP. The existing Norman WTP would be expanded with a new advanced water treatment process (membrane) system dedicated to treating river water.

Plan F is similar to Plan E except one west-side reservoir would be implemented for off-stream storage of raw water from the South Canadian River. A new membrane WTP on the west side of Norman would treat the water supply from the reservoir prior to distribution. Development of the South Canadian River, which is a water resource directly adjacent to the City, reduces conveyance infrastructure and O&M costs as compared to development of Southeast Oklahoma resources. As such, the total present worth of Plan E and F, respectively, are the third and fourth lowest of the six plans. Of the two, Plan E is monetarily comparable to Plan C. Although comparable, sensitivity to relatively poor raw water quality and limited yield issues cast Plan E as well Plan F in less favorable light non-monetarily when compared to Plan C. Furthermore, both Plans E and F must rely on the purchase of treated water from Oklahoma City to meet long-term capacity targets.

Recommended Plan Alternative

Although monetary and non-monetary evaluations have been presented, identification of the best alternate is still not obvious until a final ranking is applied to each plan. The monetary and non-monetary rankings were combined to reach a final ranking order for the six Plan Alternatives. The results are presented in Table ES-4.

TABLE ES-4
City of Norman Strategic Water Supply Plan
Matrix Analysis

	Matrix Analysis Ranking: 1 = most favorable ; 6 = least favorable			
	Factors			
Plan	**Monetary**	**Non-Monetary**	**Ranking Summation**	**Final Ranking**
A	6	6	12	**6**
B	1	5	6	**3**
C	2.5	1	3.5	**1**
D	4.5	2	6.5	**4**
E	2.5	3	5.5	**2**
F	4.5	4	8.5	**5**

As the matrix analysis indicates, Plan C ranks most favorable. In order to further ascertain the plan that is best suited to meet the needs and objectives of the City, the plans ranking closest to Plan C were further reviewed. As indicated previously, the monetary component of Plan B is most attractive. However, consideration should be given to the potential implications associated with the lack of ownership in a water supply source. Reliance on OKC treated water would be for 46 percent of the Year 2040 targeted demand. Such reliance greatly limits the City's control of their own water system. Plan E is monetarily comparable to Plan C and reduces a large portion of the reliance on OKC-treated water. However, water quality, limited yield potential, and implementation issues in an urban setting offer an unappealing position.

Conversely, Plan C includes development of the City's most cost-effective water supply source, the Garber-Wellington Aquifer, and addresses the reliance on purchased OKC-treated water. Under Plan C, the City would retain control of water quality and capacity of finished water through expansion of the raw water conveyance system and WTP. The raw water conveyance system expansion includes a new terminal reservoir, Lake Campbell, in eastern Norman, between Lake Thunderbird and the WTP. Thus, terminal storage, conveyance, and treatment capacity would be implemented to allow the City to capitalize on potential "bonus" water from Lake Thunderbird. This includes potential additional yield realized from under-utilized Midwest City and Del City allocations, the flood control pool, and/or potentially re-allocation of the conservation pool. Additionally, this infrastructure provides the City with the flexibility and leverage to develop a partnership in developing a water resource in Southeastern Oklahoma, if and when such a partnership comes to fruition. This flexibility is warranted when considering the recent interest in the three water resources in the Kiamichi River Basin—Sardis Reservoir, Kiamichi River, and Lake Hugo—by communities in Central Oklahoma. Therefore, Plan C is recommended as the preferred water supply plan to meet the City's water system needs through the 40-year planning horizon.

Figure ES-14 provides a schematic representation of the recommended City of Norman 2040 Strategic Water Supply Plan, Plan C. Also illustrated in this figure, in the bottom right corner, is how short-, mid-, and long-term target goals are met.

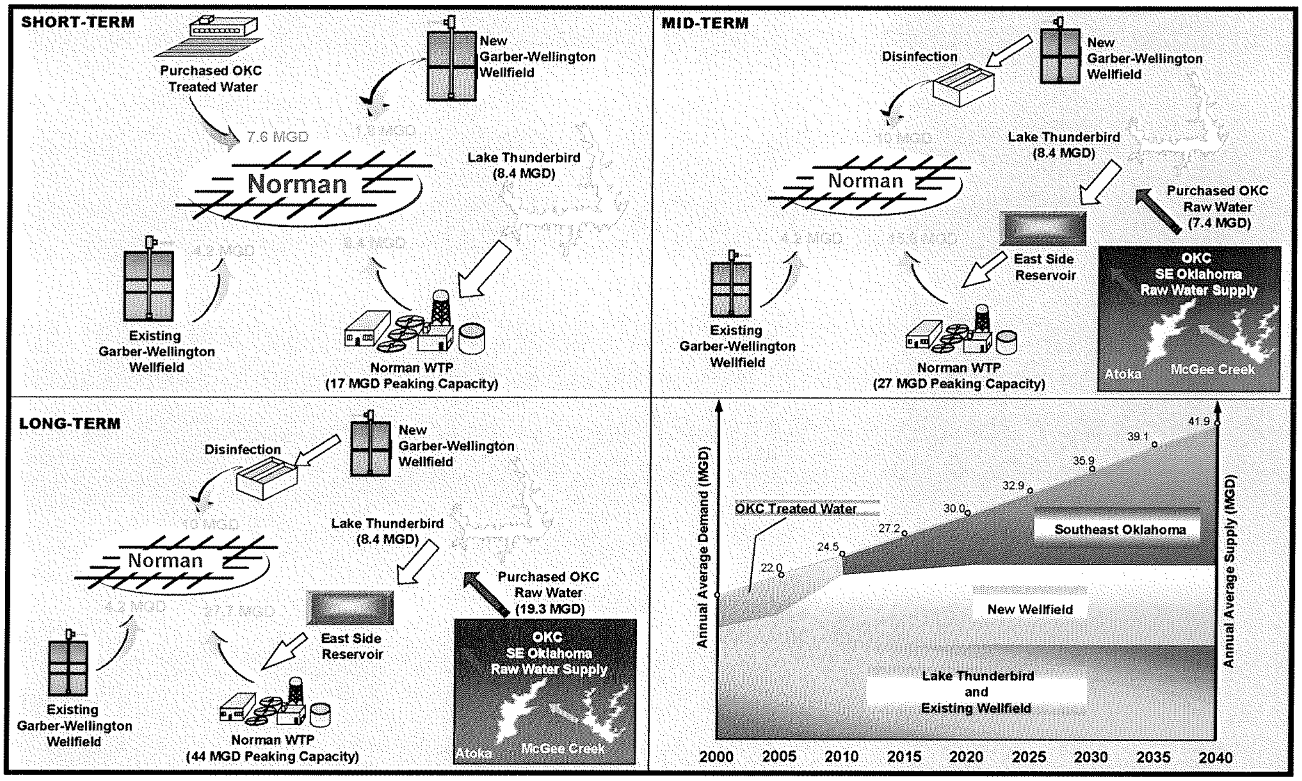


FIGURE ES-14
Recommended Strategic Water Supply Plan
Plan C – "Southeast Oklahoma"

Plan Development

Capital Improvement Plan (CIP)

To assist the City of Norman with Plan Implementation, a capital improvement plan (CIP) was developed for Plan C. Figure ES-15 shows short-, mid-, and long-term activities for the CIP.

As illustrated, development of the expanded wellfield will continue throughout both the short-term and mid-term planning periods. Thirty new wells are planned for completion by Year 2020. The groundwater disinfection system for the expanded wellfield is planned for design and construction at the existing WTP between 2008 and 2010.

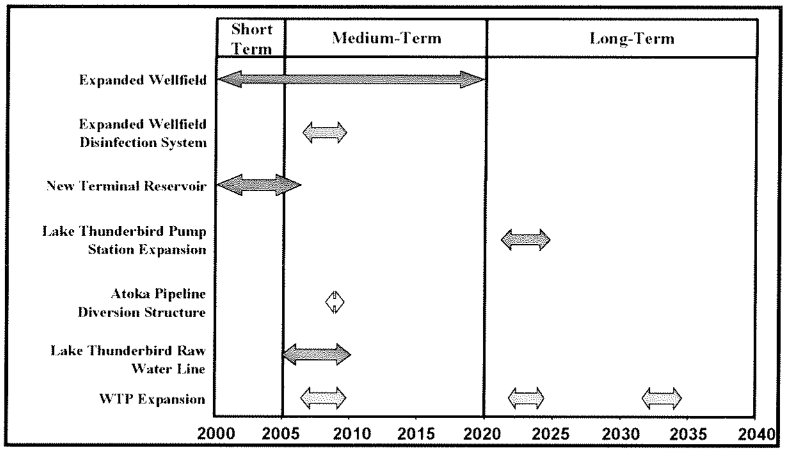


FIGURE ES-15
Short-, Mid-, and Long-Term CIP Activities

Land acquisition, design, and construction of the new terminal reservoir, Lake Campbell, and interconnecting piping is planned for the short-term period. The new raw water conveyance pipeline and Atoka Pipeline diversion structure is planned from 2005 through 2009. Expansion of the Lake Thunderbird pump station is scheduled for 2022 through 2024.

To accommodate increased raw water flows, three phases of WTP expansions are planned. The first phase is planned from 2008 to 2010 and increases the original plant capacity by 10 mgd. This expansion, coupled with existing facilities and the expanded wellfield, would serve the City until Year 2025. The second phase, which increases plant capacity by an additional 10 mgd, would occur from 2022 to 2024. Finally, the third phase to expand the total capacity of the WTP to 44 mgd would require three years beginning in 2032.

Table ES-5 provides short-, mid-, and long-term capital cost estimates associated with implementation of the CIP activities presented above.

Term	Short-Term	Mid-Term	Long-Term
CIP Needs	$12.9 Million	$39.4 Million	$28.2 Million

TABLE ES-5
Short-, Mid-, and Long-Term CIP Costs

Funding Analysis

Two funding scenarios have been developed to assist with implementation of the CIP. They are listed below.

- Scenario 1: Assumes projects are 100 percent debt-funded
- Scenario 2: Capital costs would be financed through a combination of debt proceeds and cash reserves from the operating fund

From evaluation of both scenarios, a savings of almost $70 million (present-worth basis) over the life of the CIP could be realized if Scenario 2 is adopted, relative to Scenario 1. With Scenario 2, the use of cash reserves provides balanced funding and stabilizes the debt service payment schedule.

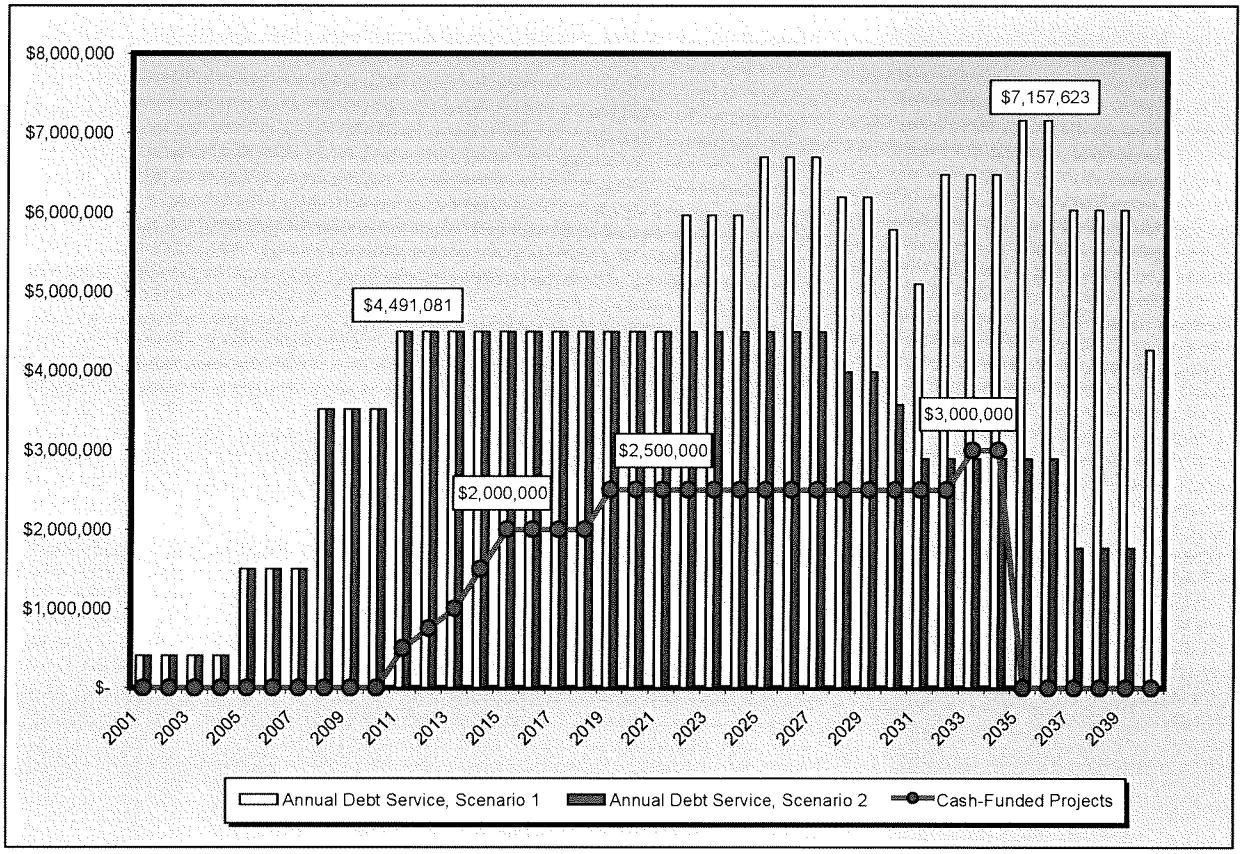


FIGURE ES-16
Norman Strategic Water Supply Plan
Funding Analysis – Projected Annual Debt Service

Figure ES-16 illustrates the annual debt service payments for both scenarios. Clearly, a manageable debt schedule can be achieved to fund the CIP which will provide a safe, abundant, and reliable water supply to the citizens of Norman for the foreseeable 40-year horizon. Moreover, with moderate cash financing, the Strategic Water Supply Plan debt schedule can not only be flattened but retired within the planning horizon.

1. Baseline Development

1.1. Introduction

1.1.1. General

Historically, the City of Norman (City) has enjoyed an adequate supply of water resources to support the community, although, water demands are fast approaching the City's water resources safe yield as well as treatment and production capacities. To meet this increasing demand and stay ahead of it well into the future, the City is faced with the task of securing additional and plentiful water supplies. Several alternative water supply sources are available to the City. Each water resource will, to some degree, require infrastructure necessary for conveyance, treatment, and/or production; and some surface water resources may require storage. This 40-Year Strategic Water Supply Plan was initiated to provide a guidance tool for best positioning the City in securing additional water resources and planning for associated infrastructure to satisfy the City's projected water demands.

As previously indicated, water supply capacity is directly associated with water demands. Specifically, the capacity of source water is related to the City's average-daily demands. Whereas, the City's water infrastructure (treatment and production) capacity is related to maximum-day demands. Accordingly, as part of the Strategic Water Supply Plan, Section 1 develops the planning horizon baseline—projected Year 2000 through 2040 average-daily and maximum-day water demands. Presented herein is the methodology used to develop this baseline.

1.1.2. Baseline Development Organization

Following this introduction, Section 1.2 presents the City's historic total population as well as future population projections. Additionally, the estimated service population for the 40-year planning horizon is presented.

Section 1.3 characterizes the historic water demands experienced by the City. Also, future water demand sensitivity is discussed. The methodology for evaluating future water demand projections based on projected service population, historic water demand trends, and demand sensitivity factors is presented along with recommended planning horizon water demand projections.

Section 1.4 discusses the need for reserve capacity and provides recommendations for water resources and water treatment/production reserve capacities over the planning horizon.

1.2. Populations

1.2.1. General

Water demand is directly proportional to population served. To evaluate the basis for demand projections for the Strategic Water Supply Plan, population projection trends were co-developed with the City of Norman Utilities and Planning Department staff for the 40-year planning horizon. Additionally, historic population data were evaluated to compare projected growth trends to those of the past. Historic population data was obtained from two sources. Unites States Census data was obtained for the City of Norman historical population up to 1990. Historic population data during the 1990s was obtained from City staff.

1.2.2. Historic Total Population

Historically, the City has experienced positive annual growth since 1890. Based on U.S. Census data, Norman's population more than doubled in the ten-year period from 1890 to 1900. By 1940, the City's population increased by more than five times the 1900 population. In the ten years spanning from 1940 to 1950, the City's population again more than doubled. From 1950 to 1990, the City's population nearly tripled. Table 1-1 presents U.S. Census data and average-annual growth rates from 1900 to 1990.

TABLE 1-1
Historic Total Population
City of Norman

Year	Total Population [a]	Growth From Previous Reported Year		
		Number of Years	Percent Change	Average Annual Growth
1890	787	-	-	-
1900	2,225	10	183	11.0
1910	3,724	10	67	5.3
1920	5,004	10	34	3.0
1930	9,603	10	92	6.7
1940	11,429	10	19	1.8
1950	27,006	10	136	9.0
1960	33,412	10	24	2.2
1970	52,117	10	56	4.5
1980	68,020	10	31	2.7
1990	80,071	10	18	1.6

Notes:
[a] Population data adopted from U.S. Census.

1.2.3. Service Population

As is the case for most municipalities located in areas with available groundwater, only a portion of the total population is connected to the City's water supply system. The population that obtains water from the City constitutes the service population. Water consumption, or demand, is closely related to service population—directly by per capita domestic use, and indirectly by commercial establishments, governmental services, and industry. Based on discussions with City staff, Norman's current service population is approximately 85 to 88 percent of the total population. The remaining population obtains water from private sources, such as private groundwater wells.

1.2.4. Current and Future Population Projections

With City input, future population and water demand projections for the 40-year planning horizon were developed. City staff reviewed and submitted a memorandum that provided population estimates for the 1990s, in addition to total and service population projections for Year 2000 through 2040.

Table 1-2 presents the anticipated populations over the planning horizon and the average-annual growth rates for 1995 through 2040. For reference, the City's memorandum is provided in Appendix A.

Annual-average growth rates for the planning horizon are comparable to growth trends during the 1980s (shown previously in Table 1-1) and the recent growth trends during the 1990s. For the planning horizon, it is anticipated that the City will continue to grow, but the annual-average growth rate will decrease from 1.6 percent in Year 2000 to 1.0 percent by the Year 2040. Overall, the City's 2040 population is projected to be approximately 1.7 times that of the 1999 population, increasing from 94,527 to 157,598.

TABLE 1-2
Population Projections
City of Norman [a]

			Growth From Previous Reported Year		
Year	Total Population [b]	Service Population [c]	Number of Years	Percent Change	Average Annual Growth
1995	87,485	76,987	5	8	1.6
1999	94,527	83,184	4	8	2.0
2000	96,065	84,538	1	2	1.6
2005	103,757	91,306	5	8	1.6
2010	111,449	98,075	5	7	1.4
2015	119,140	104,843	5	7	1.3
2020	126,832	111,612	5	6	1.3
2025	134,523	118,381	5	6	1.2
2030	142,215	125,149	5	6	1.1

TABLE 1-2
Population Projections
City of Norman [a]

			Growth From Previous Reported Year		
Year	Total Population [b]	Service Population [c]	Number of Years	Percent Change	Average Annual Growth
2035	149,907	131,918	5	5	1.1
2040	157,598	138,686	5	5	1.0

Notes:
[a] Population data adopted from 1990 through 2040 population estimates. Data set for population estimates provided in Appendix A.
[b] Total population considers 1990 Census as baseline. Population growth is based on historic annual average dwelling unit permits, 2.34 person per unit, and 95 percent occupancy of units.
[c] Service population considers 88 percent of the total population will be connected to the City water system.

1.2.5. Population Summary

For the Strategic Water Supply Plan, historic data adopted from the U.S. Census for 1890 through 1990 were reviewed. Additionally, City staff provided information for discussion on recent growth trends, service population estimates, and future population projections. Population projections were compared with historic growth trends ascertained from U.S. Census data. With these data considered, Figure 1-1 summarizes the City's historic and projected future total population as well as the estimated service population.

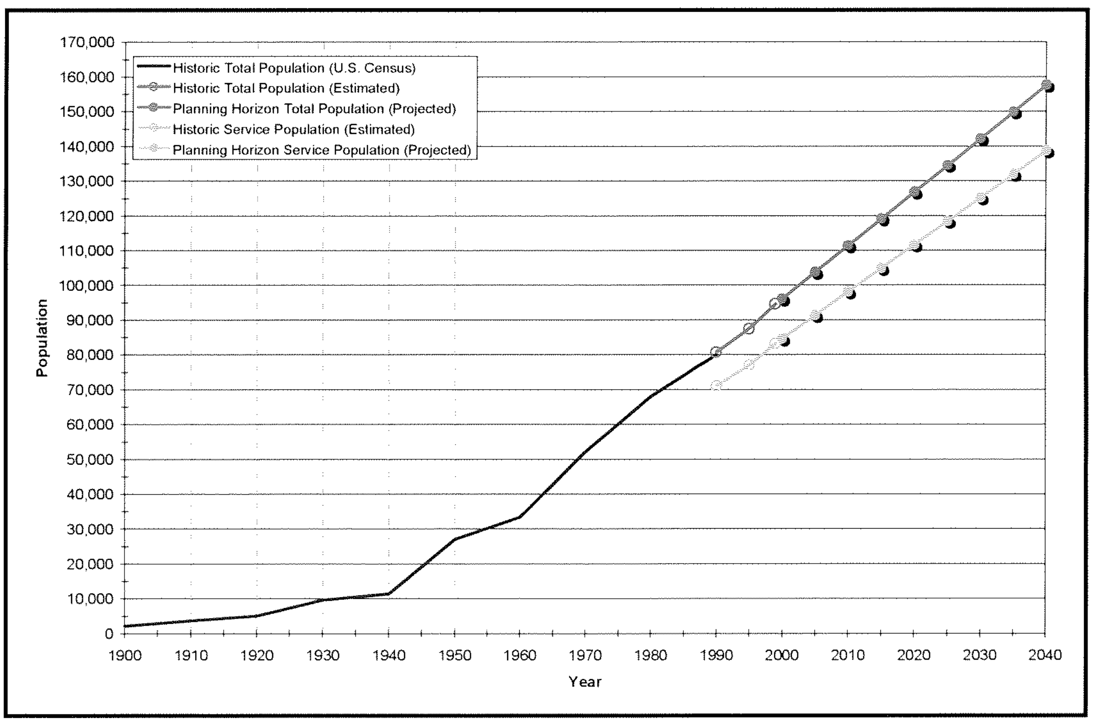


FIGURE 1-1
Population Projections

1.3. Water Demands

1.3.1. General

Currently, the City satisfies water supply needs with two resources—surface water and groundwater. The City's surface water source is Lake Thunderbird, whereas, the groundwater source is the Garber-Wellington aquifer. Associated with each supply source are treatment and production facilities. Water from Lake Thunderbird is treated at the Norman Water Treatment Plant (WTP) prior to distribution. The City's wells pump water from the Garber-Wellington directly into the distribution system. These water supply sources and treatment/production facilities are evaluated in Section 2.0, Existing System Assessment.

For Section 1.0, Baseline Development, historic water production data from the City's WTP and groundwater wells were evaluated to ascertain historic and current water demands. Water production data were obtained from WTP and Groundwater Well Daily Operation Logs. Specifically, metering data from the daily operation logs were used to ascertain:

- Average-Daily Water Demand. Average-daily water demand, sometimes referred to as average-annual demand, is the average volume of water produced per day over any given year. In other words, average-daily water demand is simply the total volume of water produced over a given year (typically in million gallons) divided by 365 days. The average-daily water demand is divided by the service population to determine per capita demand (gallons per capita per day, or gpcd).
- Maximum-Day Demand. Maximum-day demand is the maximum volume of water produced during a 24-hour period within any given year. Typically, maximum-day demand is divided by the average-daily demand to determine the maximum-day factor.

Average-daily demands over a planning horizon are critical for evaluating water resources, as sources of water supply must be available to meet the average-daily demand for any given year. Whereas, water treatment/production infrastructure must have sufficient capacity to deliver maximum-day demands for any given day.

In addition to the historic water demands discussed above, projected future average-daily and maximum-day water demands were co-developed for the 40-year planning horizon. These water demand projections were included with the memorandum from the City which also provided future population projections (see Appendix A). A water demand sensitivity analysis was performed for these projections.

1.3.2. Historic and Current Water Demands

As previously discussed, metered production data from the WTP and groundwater well daily operation logs were evaluated to ascertain historic water demands for 1990 through 1998. Additionally, January through July 1999 production data were used to ascertain current water demands for 1999. Historic average-daily and maximum-day water demands are presented in Table 1-3. Also included in the table are the calculated per capita demand (based on the estimated service population) and the maximum-day factors.

TABLE 1-3
Historic Water Demand
City of Norman [a]

Year	Service Population	Total Water Production [b] (MG)	Average Daily Demand [c] (mgd)	Per Capita Demand [d] (gpcd)	Maximum Day Demand [b, e] (mgd)	Maximum Day Factor [f]
1990	71,002	3,426	9.4	132	19.3	2.1
1991	71,758	3,460	9.5	132	18.2	1.9
1992	72,771	3,279	9.0	123	15.3	1.7
1993	73,911	3,475	9.5	129	20.6	2.2
1994	75,261	3,713	10.2	135	20.5	2.0
1995	76,987	3,913	10.7	139	20.9	2.0
1996	78,514	3,964	10.9	138	20.3	1.9
1997	79,641	3,812	10.4	131	19.8	1.9
1998	81,830	4,457	12.2	149	21.0	1.7
1999	83,184	4,270	11.7	141	22.6	1.9

Note:
[a] MG - million gallons
mgd - million gallons per day
gpcd - gallons per capita per day
[b] Water production and maximum day demand data adopted from 1989 through 1999 City of Norman Water Treatment Plant and Groundwater Wells Daily Operating Logs.
[c] Total water production within a given year divided by 365 days (per year).
[d] Ratio of average daily demand to service population.
[e] Maximum recorded water production over a 24-hour period (one day) within a given year.
[f] Ratio of maximum day demand to average daily demand for a given year.

Along with the service population, average-daily water demand has, overall, increased through the 1990s. As shown in Table 1-3, 1998 was a peak production year for the City. The City supplied an average-daily demand of over 12 mgd to its customers. This peak production is attributed to an unusually dry weather pattern during the summer. Noticeably, the maximum-day factor for this year is relatively low as compared to 1997 and 1999. The City, along with several other municipalities in Central Oklahoma, initiated water use restrictions during the summer of 1998. Without the summer-adopted water restriction policies, the 1998 demand and maximum-day factor would undoubtly have been greater.

Current average-daily demand is approximately 12 mgd, based on 1999 water production records. Although 1999 was a more weather-typical year, water production staff indicated that the system experienced peak water demands. During those months of 1999, the City had to meet a maximum-day demand of 22.6 mgd—almost twice the average-daily water demand. Additionally, City staff indicated that the monthly-average water production for the month of August 1999 approached 20 mgd.

1.3.3. Demand Sensitivity

As discussed previously, water demands are influenced by weather patterns and water use restrictions. In addition to these factors, water rate structures, per capita consumption, population growth, and conservation measures impact water demands. These sensitivity factors are discussed below.

Service Population and Per Capita Demand

The projected future population for the City has been presented previously. However, actual population growth and resulting water demands can vary significantly from what has been projected over the planning horizon. Additionally, the University of Oklahoma and the Town of Hall Park could potentially become relatively significant outside users over the 40-year planning horizon, depending on their growth, water use, and acceptable water purchase/supply agreements.

As previously discussed, service population directly impacts water demand through unit usage or per capita consumption. Since 1950, the U.S. Geological Survey (USGS) performs a study every five years to determine water use trends in the United States. Table 1-4 provides a summary of the water use trends as reported by USGS for 1985, 1990, and 1995. Additionally, for comparison, the City's historical per capita consumption is provided for these same years.

TABLE 1-4
Historic Per Capita Water Demand
National, State, County, and City Trends

Year	United States [a] (gpcd)	State of Oklahoma [a] (gpcd)	Cleveland County [a] (gpcd)	City of Norman [b] (gpcd)
1985	183	184	149	104
1990	184	193	122	132
1995	179	194	121	139

Note:
a Data adopted from U.S. Geological Survey - Water Use Trends.
b 1985 data adopted from City of Norman Master Water Plan, 1992.

As shown, the City's per capita demand has historically been below that of the U.S. and the State of Oklahoma averages. On the other hand, the City's per capita demand is greater than the average for Cleveland County. Noteworthy, per capita demand for the City has varied on an annual basis, as shown previously in Table 1-3. However, as depicted in Table 1-4, the City's per capita demand, overall, is increasing.

The USGS reports that 1995 is the first time since 1950 that the U.S. average per capita demand has declined. However, the USGS also reports that per capita demand for the U.S. as a whole is expected to increase in the future. For the reported years in Table 1-4, the average per capita consumption for the State of Oklahoma has continued to increase, as did that of the City's. Over the 40-year planning horizon, the City's per capita demand is expected to continue to increase.

Weather

Perhaps the most significant factor that impacts per capita consumption on an annual basis is weather. In general, per capita demand increases when precipitation decreases. Without restrictions, hot dry weather prompts significantly higher water use. This phenomenon is typically attributable to increased irrigation demand. Peak water demand in 1998 is an illustration of such a phenomenon. On the other hand, wet cool weather prompts significantly lower use. In general, future water demands are projected based on "normal" precipitation, as the frequency of extreme weather patterns is typically low and such events have short duration when compared to long-range planning such as this 40-Year Strategic Water Supply Plan.

Water Rates

Alternative water rates can be structured to promote conservation and help funding of water resources and infrastructure to meet water demands. In the U.S., there has been a relatively dramatic move of late from a declining block-rate structure (which charges lower rates for each successive increment of water use) to more conservation-priced programs. As reported in a study by the American Water Works Association, from 1986 to 1994 the number of water providers nationwide using declining block rate structures decreased by over 21 percent. For this reported time period, the number of providers using conservation-type programs increased from 39 percent to over 60 percent. Of this overall increase in conservation-priced programs, the number of providers using an inverted block-rate structure (charges higher rates for each successive increment of water use) increased from 7 percent in 1986 to approximately 23 percent in 1994. Figure 1-2 summarizes the national trend in water rate structures.

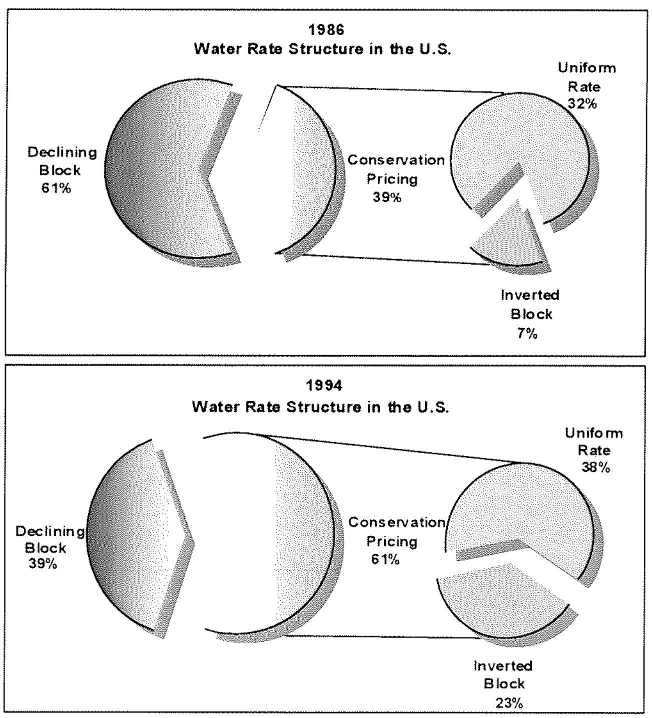


FIGURE 1-2
Changes in Water Rate Structures in the U.S.

Although there is an increasing trend in conservation-priced programs in the U.S., impacts of water rates on water use have varied widely between communities because of differing conditions, such as climate, cost of supplying water, customer demographics, and local economic conditions. Studies, conducted by the USGS, have shown that a 10 percent increase in rates may have a range in effect from no change in water use to reducing the overall use by as much as 12 percent.

Alternative rate structures can include:

- Inverted Block Rates. As previously mentioned, this rate structure charges higher rates for each successive increment of water use. The conservation impact of this rate structure depends on climate, the size of the blocks, and the prices of each block. If the quantity of blocks is small and the progessivity of the blocks rates are steep, the conservation effects can be significant, particularly in arid climates. It tends to achieve relatively greater impacts on peak months (summertime) use than annual use.
- Seasonal Rates. To match rates with demand, this rate structure charges rates directly proportional to overall demand over specified time periods. The seasonal rate structure theory is also common in the gas and electric service industries. For water systems, seasonal higher rates are sometimes implemented to achieve conservation benefits relative to peak month (summertime) water demands. The specific impacts are mostly related to reduction in outdoor water use, such as irrigation and car washing. The magnitude of the conservation effect depends on proper advance determination of the level of the seasonal rate, public education regarding implementation of seasonal rate structure, and the frequency of billing. Annual conservation impacts may be as much as 10 percent and the impacts on peak-month can be much larger.
- Uniform Rates. A uniform rate structure sets a constant unit price for water use, regardless of the quantity of water consumed. Conservation tends to have the greatest impact on an annual basis, but can impact peak-month use. To enhance conservation, uniform rate structures are sometimes modified to include a seasonal rate component.

In May 1999, the City initiated, by vote, a "modified inverted rate" structure. In short, the City's water rate structure is based on a three-block declining rate for water use up to 15,000 gallons per month. For water use above 15,000 gallons per month, the rate structure is elevated to excess-use rates within a two-block inverted rate structure. For excess-use rates, the first water-use block is defined from 15,001 to 20,000 gallons per month water use. The second block is defined for 20,001 or more gallons per month water use. Considering the modified inverted-block rate has just recently been approved, conservation trends associated with the rate structure are in their infancy and therefore incomplete for long-term projections. However, as part of the sensitivity analysis, potential conservation was considered for projecting water demands over the planning horizon. Future water-demand projections are presented in Section 1.3.4.

Conservation/Restriction Measures

Like rate modifications, the impacts of conservation methods and use restrictions have varied impacts on water use. Conservation programs are often used to effect long-term reductions in use. Restrictions are typically emergency measures to deal with short-term shortages in available water supply to customers.

Conservation programs can be targeted at outdoor water use, indoor use, or both. Outdoor programs include such items as low-water-use landscaping, timers on sprinkler systems, and sweeping sidewalks and driveways rather than hosing them. Indoor conservation programs include installation of low-flush toilets, shower-flow restrictors, low-use clothes and dishwashers, full-load clothes and dishwashing, shorter showers, and a variety of other educational tips to avoid waste while using tap water. In many cases, these measures can result in water-use reduction of up to 50 percent on an individual basis. Collectively, the impact is much less, typically only a small percent on an annual basis because of limited active participation by users. The City has initiated a public education program geared specifically towards water conservation. With this in mind, the sensitivity analysis considers potential conservation associated with this education program over the planning horizon.

Examples of restrictions include "odd-even" watering limitations and prohibition of outside water use. Odd-even systems, where homes with odd numbered addresses irrigate only on odd-numbered dates and vice versa, can effectively reduce maximum-day demand because only half the customers are allowed to irrigate on any given day. However, peak-month and average-daily use are relatively unaffected. Prohibitions on outside water use, primarily irrigation, can effect water use over a longer period of time than odd-even systems. Annual demands can be reduced by as much as 10 percent or more by prohibiting outside use (depending on type of developments, landscaping, weather, etc.).

1.3.4. Future Water Demand Projections

As previously indicated, with City input, future water demand projections for Years 2000 through 2040 were developed. These water demand forecasts are presented in Table 1-5.

TABLE 1-5
Year 2000 – 2040 Water Demands
Projected Normal Trend

Year	Service Population	Per Capita Demand (gpcd)	Average Daily Demand (mgd)	Maximum Day Factor	Maximum Day Demand (mgd)
2000	84,538	136	11.5	2.0	23.0
2005	91,306	146	13.3	2.0	26.7
2010	98,075	156	15.3	2.0	30.6
2015	104,843	166	17.4	2.0	34.8
2020	111,612	176	19.6	2.0	39.3
2025	118,381	186	22.0	2.0	44.0
2030	125,149	196	24.5	2.0	49.1
2035	131,918	206	27.2	2.0	54.4
2040	138,686	216	30.0	2.0	59.9

Notes:
gpcd – gallons per capita per day
mgd – million gallons per day

A sensitivity analysis was performed on the projected water demands for the planning horizon. Basically, sensitivity analysis aids in the evaluation of varying trends in future projections, as variables inherently become more uncertain as the projections move from short-term to long-term. For this sensitivity analysis, the projections presented in Table 1-5 were considered as the expected normal demand trends. Sensitivity factors for high and low water demand trends were evaluated based on comparing historic population and water-demand growth trends to most recent trends experienced by the City. The following methodology was used to define sensitivity factors range of possibilities.

Service Population Sensitivity

- Dwelling Units. City-provided population estimates were based on the annual-average dwelling unit permits from 1991 through 1998 (692 dwelling units per year). The sensitivity analysis considered differing growth rates based on comparing historic trends to the most recent trends in dwelling unit permits. The average dwelling unit permits for 1990 through 1998 (646 dwelling units per year) was slightly less than the 1991-1998 average. On the other hand, most recent permits for 1997 and 1998 indicate a potential higher growth trend (848 dwelling units per year).
- Occupancy Rate. Population forecasts were based on equating dwelling units to population by considering 2.34 persons per unit and a conservative 95 percent occupancy rate. City planning staff indicated the current overall dwelling unit occupancy rate could be as high as 98 percent.
- Service Population. Approximately 88 percent of the City's total population is projected to constitute the City's service population. As up-scale communities continue to develop and become more urbanized, per capita water use and overall water demand tend to increase. With this increase in water demand, the community will typically become more reliant on water systems (in lieu of private supply) to meet consumption. In these cases, more people from the total population will connect to the water system, which effectively increases the ratio of service population to total population. However, based on the most recent development trends, this urbanization phenomenon does not appear to be the case for the City of Norman. City staff indicated that approximately 15 percent of the most recent dwelling unit permits include a private water supply. As such, based on most recent trends, the future service population could be lower—85 percent of the total population.
- Saturation. Saturation is the point at which land use is maximized and little growth can occur. As land saturation is approached, the rate of development declines, and therefore, population growth rates become asymptotic. The City's corporate boundary encompasses in excess of 189-square-miles. Of this total land area, approximately 73-square-miles is developed. However, not all of the developed land is at full capacity, and therefore development is still occurring within a portion of this land. Of the remaining 116-square-miles that are undeveloped, the City's land-use plan (*Norman 2020 Land Use and Transportation Plan*) estimates that approximately 80-square-miles are suitable for future development. A large portion of this land reaches into far eastern Norman, hence remote from the City's existing water system. In any event, City staff indicated that sufficient land is available within and directly bordering the City's current service area for future development associated with the service population projections

presented previously. This considered, land saturation is not foreseen for the City over the 40-year planning horizon.

Water Use Sensitivity

- Per Capita Demand. Based on the City's 1990 through 1999 average per capita demand, the Year 2000 per capita demand is projected to be 136 gallons per person per day. However, based on water use for 1998 through July 1999, the per capita demand in Year 2000 could be as high as 141 gpcd. Additionally, per capita demands are expected to increase by 2.0 gpcd per year over the planning horizon. The sensitivity analysis also considered an increase in per capita demand of only 1.6 gpcd per year—a 20 percent reduction due to potential conservation associated with the City's rate structure, conservation education program, or both.

- Maximum Day Factor. As previously discussed, the 1998 maximum-day factor, without summer water use restrictions, would have likely been higher. Based on historic data, excluding 1998, the average maximum-day factor is approximately 2.0. However, the City has initiated a policy of incorporating a "safety-factor" of 1.05 into the projected maximum-day factor for the planning horizon. Essentially, this safety factor is a method of developing reserve capacity into the City's water system (reserve capacity is discussed in Section 1.4). With this in mind, the normal maximum-day factor for the planning horizon is estimated to be 2.0. The sensitivity analysis also considered a maximum-day factor as low as 1.9 (minimum factor from 1995 through 1999, excluding 1998). In addition, a higher maximum-day factor of 2.2 was considered, as historically the City has had to meet a maximum-day demand over twice that of the daily average.

The sensitivity factors, discussed above, were used to evaluate potential trends in water demands over the planning horizon. Figures 1-3 and 1-4 summarize the sensitivity analysis for the projected average-daily and maximum-day water demands, respectively. As depicted, the sensitivity band is bound between the projected high- and low-water demand trends. As previously mentioned and depicted by the broadening of the sensitivity band in the figures, water demands can vary significantly over the planning horizon. However, the projected normal demand curves reasonably represent future demands over the planning horizon.

1.3.5. Water Demand Summary and Recommendations

WTP and Groundwater Wells Daily Operating Logs were reviewed to ascertain historic average-daily and maximum-day water demands for the City. Additionally, water demand projections for the 40-Year planning horizon were developed with City staff input. In light of this water supply plan, these water demand projections were developed based on performing a sensitivity analysis. This analysis considered population and water use sensitivity factors ascertained from historic as well as most recent trends in total population growth, service population, land availability, per capita water use, maximum-day water use, rate structures, weather, and conservation measures.

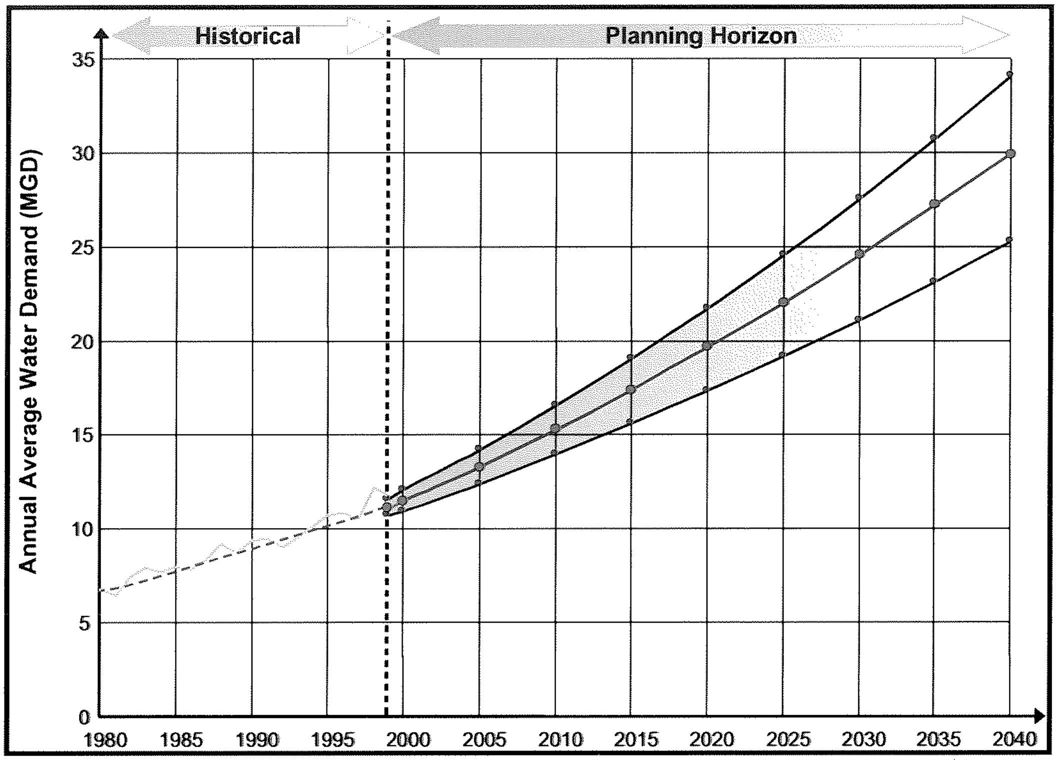


FIGURE 1-3
Annual-Average Water Demand Projections

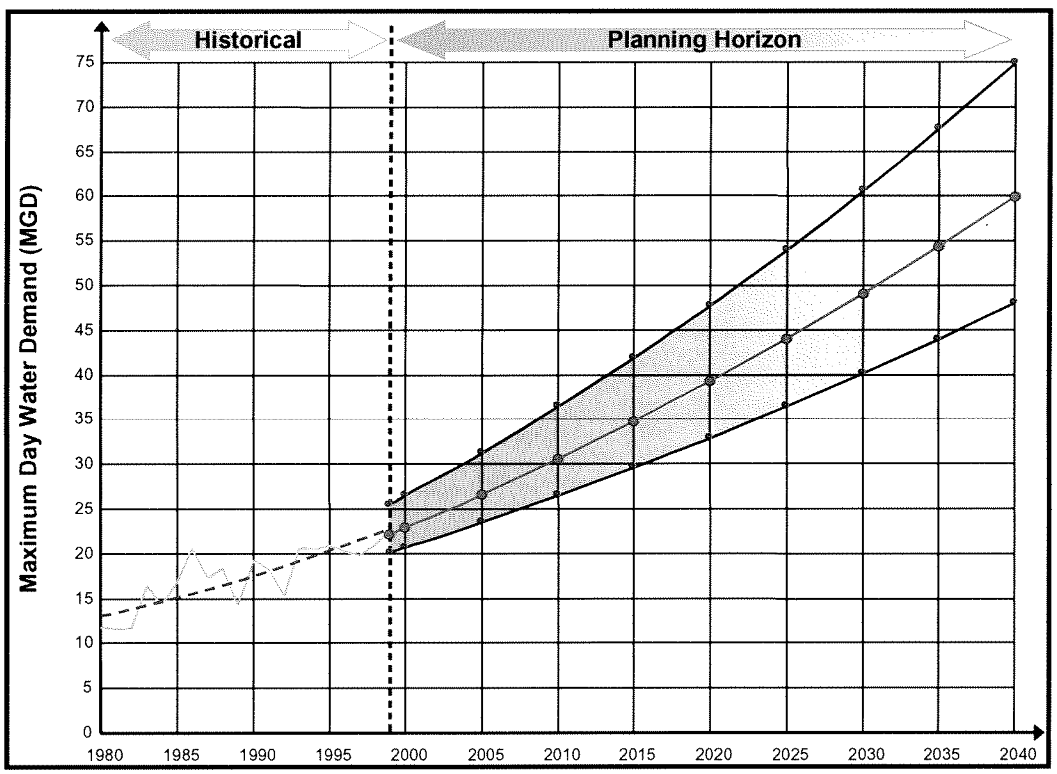


FIGURE 1-4
Maximum-Day Water Demand Projections

Based on the sensitivity analysis, adopting the projected normal water demand trends is recommended for this Strategic Water Supply Plan. Considering the projected normal trend, average-daily water demand is projected to increase from 11.5 mgd in Year 2000 to 30.0 mgd in Year 2040. Similarly, maximum-day water demand is projected to increase from 24.1 mgd to 62.9 mgd by Year 2040. Figure 1-5 summarizes the projected average-daily and maximum-day water demands.

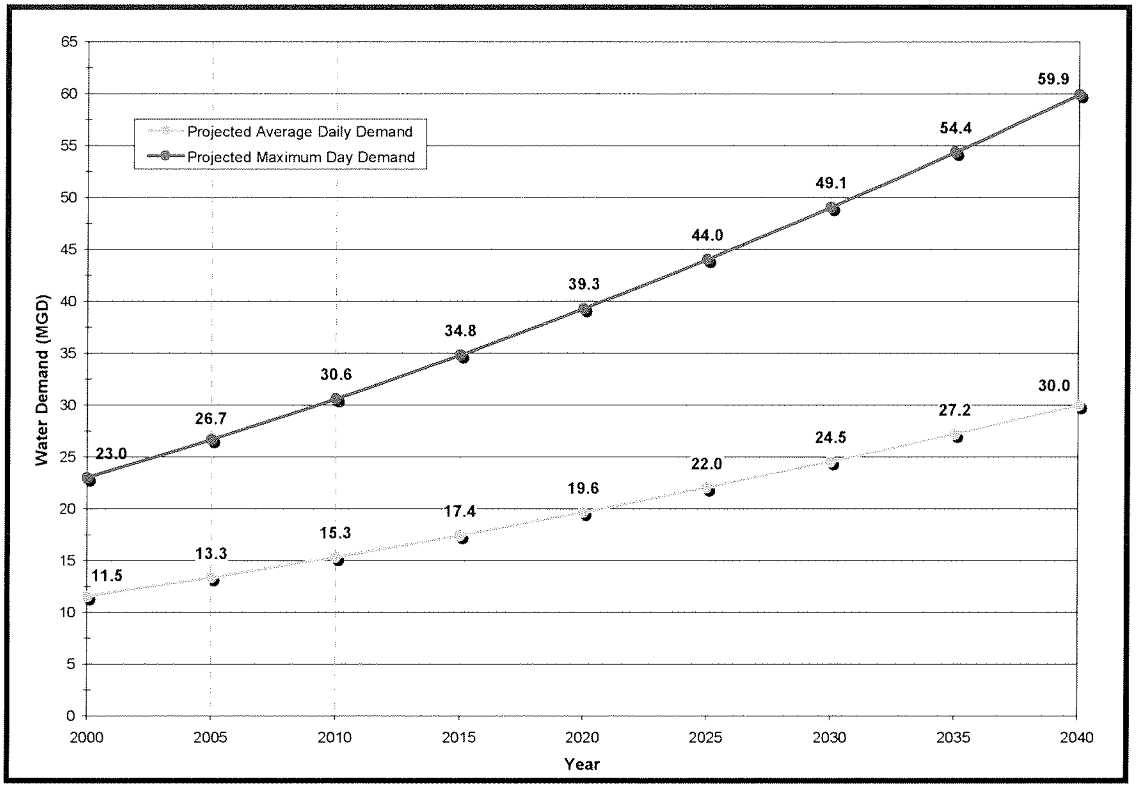


FIGURE 1-5
Average-Daily and Maximum-Day Water Demands
Projected Year 2000-2040 Normal Trends

1.4. Reserve Capacity

1.4.1. General

Reserve capacity is intended to provide additional capacity beyond the expected water use of the system over the 40-year planning horizon. In effect, an acceptable reserve capacity provides an effective tool for staging water resources and capital improvement projects over the planning horizon while maintaining system reliability to meet water demands.

A primary goal of this Strategic Water Supply Plan is to ascertain water resources and associated treatment/production facilities to best position the City in meeting water demands over the 40-year planning horizon. To this end, it is recommended that future capital improvement projects for the City's water resources and treatment/production facilities should be proposed with an acceptable reserve capacity in mind. To characterize acceptable, a study was performed of current trends practiced by other municipalities. This information was used to ascertain a reserve capacity benchmark for the City's water resources and treatment/production facilities. In addition, federal and state regulatory codes were reviewed as references for reserve capacity. A summary of the pertinent data collected during the evaluation and the methodology used to ascertain the reserve capacity benchmark for the 40-year planning horizon is presented in the following paragraphs.

1.4.2. Reserve Capacity Needs for the City of Norman

As depicted by the sensitivity analysis presented in the previous section, population and service population growth, per capita water use, maximum-day water use, weather, water rates, and conservation measures impact future water demands. These water demand sensitivity factors can, and likely will, vary significantly over the 40-year planning horizon. As a result, water demands will vary over the same planning horizon. Although the sensitivity analysis was performed to normalize the expected water demand trends for planning purposes, reserve capacity provides a means for the City to meet increases in water use above the expected trends due to rapid population growth, industry or commercial development, and per capita water use.

Obtaining additional water resources (for instance, water rights) will typically require a much greater implementation period as compared to implementing expansion of treatment/production facilities. Development of a new water resource can range upwards from 10 to 20 years (or even longer), depending on the type of resource, location with respect to the system, water rights negotiation and purchasing, land acquisition, required infrastructure, etc. Whereas for water treatment/production facilities, the typical implementation time will range from 2 to 5 years. Reserve capacity serves to maintain system effectiveness to meet demands while water resources and water treatment/ production facilities are implemented. Considering typical implementation schedules, a greater reserve capacity is required for water resources than for water treatment/ production facilities.

1.4.3. Identified Reserve Capacity Trends

Current Available Reserve Capacity to the City of Norman

As previously discussed, total capacity, or safe yield, of water resources (surface water reservoirs and groundwater aquifers) must be available to meet average-daily demands experienced by the system. Safe yield is the sustainable capacity from a water resource that is in balance with average or near-average recharge conditions. In other words, safe yield refers to the water capacity that can be produced from each water resource without depleting, or mining, the resource. Surface water reservoirs are naturally recharged from water runoff over the reservoir's watershed or, in some instances, from groundwater supplying tributaries and the reservoirs. Groundwater aquifers are naturally recharged from water percolating through the soil. In some cases, surface water and groundwater resources can be artificially recharged or augmented to increase safe yield.

Lake Thunderbird is operated by the Central Oklahoma Master Conservancy District (COMCD). One of its main purposes is to provide raw water supply to the Cities of Norman, Midwest City, and Del City. As such, through a contract agreement with the

COMCD, the lake's safe yield is allocated between the three cities. The City of Norman's annual-average water allocation from Lake Thunderbird is 8.4 mgd. Additionally, based on discussion with City staff, the City's existing wellfield with 31 wellheads can yield approximately 4.2 mgd, sustained, without significant change to the produced water quality or reduction to aquifer levels. Considering these factors, the combined annual-average yield from Lake Thunderbird and the Garber-Wellington aquifer is approximately 12.6 mgd. This total annual-average yield, less current average-daily demand, contributes to the City's current available water resource reserve capacity. Although preliminary from the standpoint of evaluating water resources, the City currently has approximately 14 percent reserve capacity available for water resources. Each of the City's existing water resources is evaluated in greater detail in Section 2.0, Existing System Assessment. Table 1-6 summarizes the City's current water resource reserve capacity.

TABLE 1-6
Water Resources
Current Available Reserve Capacity

Parameter	Capacity (mgd)
Water Resources	
Wellfield (31 wells)	4.2
Lake Thunderbird Allocation	8.4
Total	12.6
Capacity and Demand	
Total Water Resource Capacity	12.6
1999 Average Daily Demand	11.7
Available Reserve	0.9
Percent Reserve Capacity	7%

Associated with each water resource is the need for infrastructure to produce water to supply maximum-day demands. For Lake Thunderbird, production infrastructure includes the raw water transmission line, WTP, and high-service pump station. Lake Thunderbird serves as storage to shave the difference between maximum-day and average-daily demands. To utilize this storage, the WTP has a rated capacity of 17 mgd. However, as the WTP is remote from Lake Thunderbird, water supply to the WTP is dependent on the capacity of the raw water conveyance infrastructure (raw water pump station and transmission line). Unfortunately, the raw water conveyance capacity is limited to 14 mgd. Consequently, the maximum-day production capacity of the WTP is limited to 14 mgd. This water production capacity is augmented with water produced from the City's wellfield to meet maximum-day demands.

The City's water system is strategically located over the Garber-Wellington aquifer. As such, the Garber-Wellington aquifer provides the City with natural storage to help meet maximum-day demands, similar to Lake Thunderbird. In other words, the City's groundwater wells pump from this available storage to meet maximum-day demands. Noteworthy, the benefits of this natural storage in the Garber-Wellington aquifer would not be fully available if the aquifer was remotely located from the water system.

Maximum production capacity from the Garber-Wellington is dependent on hydraulic characteristics and physical constraints based on geologic and hydrogeologic factors of the aquifer. The hydraulic properties of the Garber-Wellington aquifer include hydraulic conductivity, transmissivity, and specific capacity. These properties are measures of the rate of water flow and production that can be expected in the aquifer. These factors and the evaluation of the Garber-Wellington aquifer are discussed in greater detail in Section 2.0.

The City's existing wellfield is comprised of 31 producing water wells within the Garber-Wellington aquifer. Assuming a charged aquifer and all 31 wells in operation, this wellfield can produce approximately 8.1 mgd over short-term duration (approximately 30 days). However, this peak pumping capacity is not sustainable, as aquifer hydraulic characteristics cannot support flow through the aquifer at this rate continually. As such, cones of depression from each well lower the aquifer hydrostatic level (referred to as aquifer drawdown) and overlap cones from adjacent wells (well interference). Combined, these factors limit production capacity and reduce peak pumping from the aquifer over the long-term.

Considering the WTP and wellfield maximum production capacities, the City's current water production capacity to meet maximum-day demands is approximately 22.1 mgd. Comparing this maximum production capacity to the 1999 maximum-day demand of 22.6 mgd indicates that the current maximum-day demands have exceeded the City's production capacity, and hence all of the City's available reserve capacity for treatment/ production facilities. Although maximum-day demands have exceeded production capacity, the City has been able to meet demands through in-system storage. Table 1-7 summarizes the current treatment/production reserve capacity analysis.

TABLE 1-7
Water Treatment/Production
Current Available Reserve Capacity

Parameter	Capacity (mgd)
Facility	
Wellfield (31 wells)	8.1
Water Treatment Plant	14
Total	22.1
Capacity and Demand	
Total Production Capacity	22.1
1999 Maximum Day Demand	22.6
Available Reserve	0
Percent Reserve Capacity	- 2.2 %

Reserve Capacity Practiced by Other Municipalities

Several municipalities were selected for survey of current trends in reserve capacities. In this benchmarking effort, cities having similar characteristics as the City of Norman were polled. This was based on population, climate, growth potential, and proximity to major university campuses and metropolitan areas. As a preliminary effort, cities within the South-Central Region of the U.S. were contacted and surveyed. This effort included cities in Oklahoma, Texas, Kansas, Nebraska, and Colorado. In addition, other states from different regions and climate zones in the country were surveyed to provide a more complete background and basis of comparison. These states included Arizona, Utah, Iowa, Alabama, Georgia, and South Carolina. In total, 12 cities that met the selection criteria were identified and included in the benchmarking evaluation.

The survey effort included contacting water utility personnel from each municipality. Then, reserve capacity and, to some extent, the degree to which the municipality met the selection criteria, were identified based on discussion with respective personnel. Table 1-8 provides a summary of the benchmarking survey. In addition, Figure 1-6 graphically compares the cities' water resource reserve capacity to the City of Norman's reserve capacity.

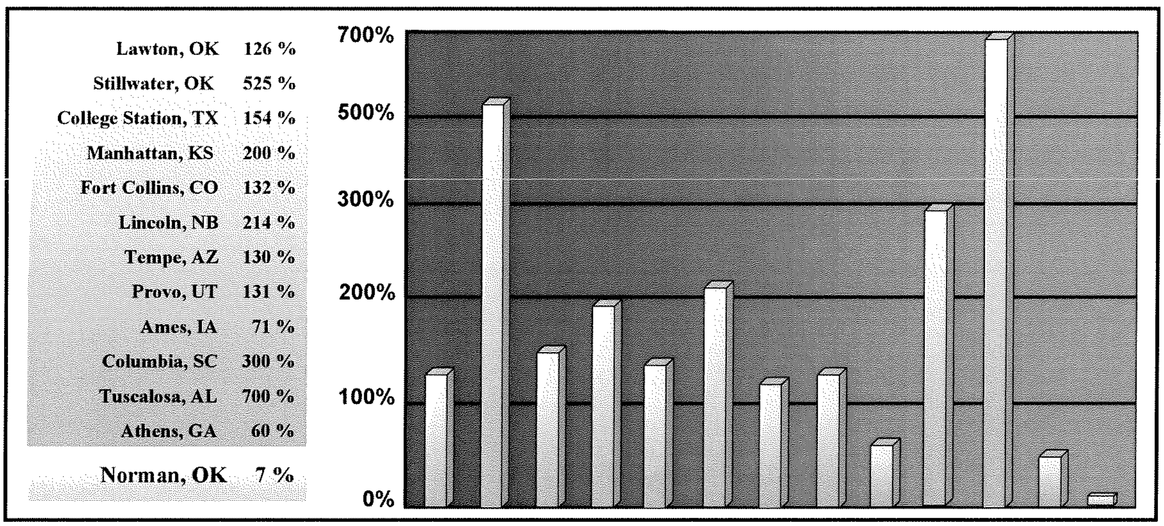


FIGURE 1-6
Water Resource Reserve Capacity Comparison

As depicted, all 12 cities included in the survey maintain available reserve capacity for water resources. For the cities polled, the available reserve capacity for water resources range from 60 to 700 percent of the current average-daily demand, while the City of Norman's is 14 percent. Available reserve capacity should not be taken as the minimum reserve targeted by the surveyed cities.

The length of time needed to increase water supply either by obtaining water rights, or combining with another water supply system can be relatively long. As such, cities typically purchase the maximum available water rights to secure a water resource for long-term water supply and to support associated investment in infrastructure. For example, the City

Table 1-8

Water Utility Reserve Capacity

City Benchmarking Survey

					Water Resources			Treatment/Production			
City	Population 1996 Census Report	Nearest Major Metropolitan City	University	Average Annual Rainfall	Current Average Daily Demand (mgd)	Total Water Resources Capacity (mgd)	Available Reserve Capacity	Current Maximum Day Factor	Current Maximum Day Demand (mgd)	Total Treatment/ Production Capacity (mgd)	Available Reserve Capacity
Norman, OK	**90228**	**Oklahoma City**	**University of Oklahoma**	**35 in**	**11.7**	**12.6**	**7%**	**1.9**	**22.6**	**22.1**	**-2.2%**
Lawton, OK [a]	82,582	Oklahoma City	Cameron University	30 in	19.5	44	126%	1.9	36.7	35	-4.9%
Stillwater, OK [a]	38,487	Tulsa, Oklahoma City	Oklahoma State University	33 in	8.0	50	525%	1.1	9.0	12	25.0%
College Station, TX [b]	58,757	Houston	Texas A&M University	39 in	7.1	18	154%	2.5	17.5	**	**
Manhattan, KS	42,117	Kansas City	Kansas State University	32 in	8.0	24	200%	1.9	15.0	20	25.0%
Fort Collins, CO	104,196	Denver	Colorado State University	15 in	26.7	62	132%	2.5	66.4	74	10.3%
Lincoln, NB	209,192	Omaha	University of Nebraska	29 in	35.0	110	214%	2.4	85.0	110	22.7%
Tempe, AZ	162,701	Phoenix	Arizona State University	9 in	43.5	100	130%	1.7	73.0	90	18.9%
Provo, UT [b]	99,606	Salt Lake City	Brigham Young University	22 in	26.0	60	131%	2.0	52.0	**	**
Ames, IA	47,698	Des Moines	University of Iowa	35 in	7.0	12	71%	1.4	9.5	12	20.8%
Columbia, SC	112,773	Columbia	University of South Carolina	48 in	55.0	220	300%	1.8	98.5	130	24.2%
Tuscaloosa, AL [a]	82,379	Birmingham	University of Alabama	53 in	25.0	200	700%	1.6	40.0	40	0.0%
Athens, GA	89,405	Atlanta	University of Georgia	49 in	17.5	28	60%	1.4	24.0	28	14.3%

Notes:

[a] Are currently expanding water/production infrastructure.

[b] The cities of Provo, UT and College Station, TX provide in-line treatment and therefore treatment/production capacity is not applicable.

of College Station, Texas, has a policy for securing water resources to satisfy projected demands over a 50-year planning horizon. With this considered, securing water resources for long-term supply will often result in increased reserve capacity during the short- and mid-term phases. Infrastructure in turn is phased to meet short- to mid-term water demands and facility life-cycle projections. As such, infrastructure inherently has less reserve capacity.

The reserve capacity range for the treatment/production facilities range from less than zero to 25 percent of the maximum-day demand as is depicted on Figure 1-7.

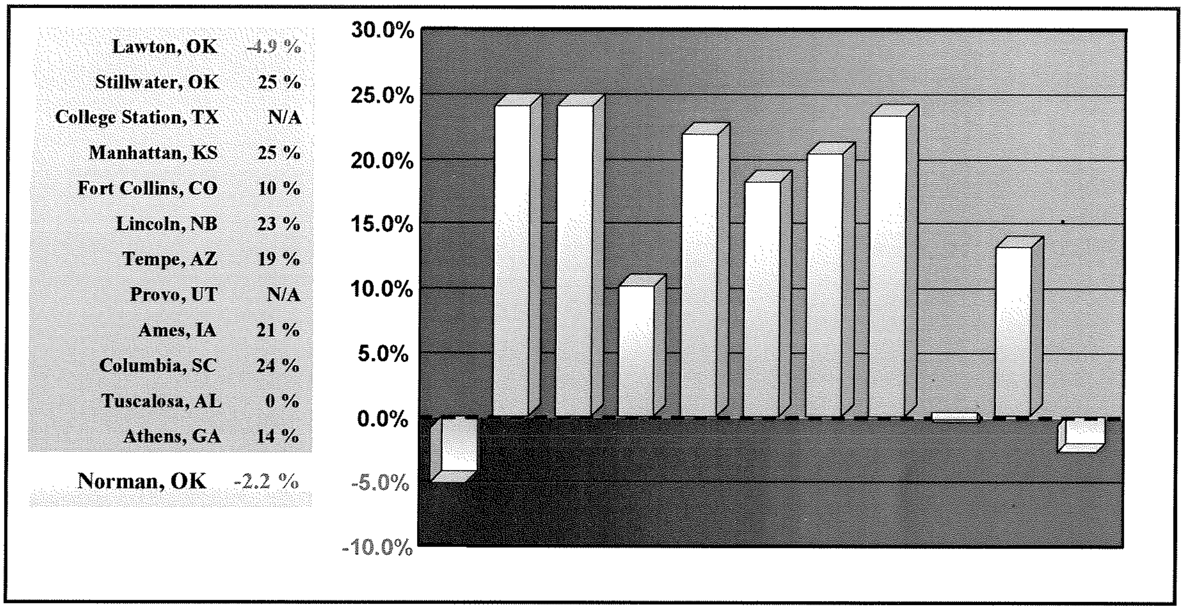


FIGURE 1-7
Treatment/Production Reserve Capacity Comparison

For the two cities that are at full production capacity (zero percent reserve capacity), treatment plant upgrades are currently underway to add additional plant capacity. Regarding these two cities, in-system storage allowed the maximum-day demands to be met, but this caused undue strain on the system. This illustrates the need to design treatment/production facilities with a reserve capacity in mind.

With larger municipalities (for instance, with service populations greater than 250,000), reserve capacity encroachment is often used as a trigger to initiate capital improvement construction. None of the surveyed cities have a reported capital improvements trigger policy, although, they did indicate loose guidelines were used to initiate expansion. For water treatment/production facilities, in general, the planning and design phases will begin when reserve capacity decreases to approximately 10 percent of the total production capacity.

Reserve Capacity Identified by State Regulatory Guidelines

As previously mentioned, a survey of federal and state regulatory codes was performed to identify suggested reserve capacity under guidance rules and/or standards. Regulatory codes from several states within the South-Central Region, including Oklahoma, Arkansas, Louisiana, Kansas, and Texas, were included in the survey.

For all states within the South-Central Region, the findings were identical. These states do not set guidelines that specify reserve capacity. The regulations simply state that the water resource and related treatment and distribution systems must be designed to meet the maximum-day demands of the service area. As discussed herein, evidenced by recent summer rationing, and as confirmed in Section 2, Existing System Assessment, the City of Norman has insufficient existing production capacity to meet historical and future maximum-day demands of the service area. No provisional guidelines are made for reserve capacity, leaving this to the sole discretion of the individual municipality.

1.5. Planning Capacity Summary and Recommendations

Several municipalities located throughout the U.S. were surveyed to identify suggested or available reserve capacity as it relates to water resources and treatment/production facilities.

All twelve cities polled have available reserve capacity for water resources. Available reserve capacity should not be taken as the minimum reserve target. In securing water resources, the total available water capacity from the supply source is typically obtained. As such, available water capacity can significantly exceed the minimum target reserve capacity, especially during the short- to mid-term phases of the project.

For the City of Norman, targeting a planning capacity as a function of demand and an assumed minimum implementation period of 20-years is recommended for obtaining new water resources (including evaluation and/or development of identified water resources, securing water rights, and design and construction of associated raw water conveyance infrastructure). To this end, the average-daily water demand curve (the projected normal trend from Section 1.3) was transposed on an annual basis over a 20-year period. With this methodology, the minimum target water resource planning capacity varies over the horizon based on the shape of the demand curve. The resulting water resource planning capacity is depicted on Figure 1-8.

From the survey, 83 percent (10 of the 12 cities) have an available water treatment/production reserve capacity. The two cities that are at production capacity currently have capital improvement construction projects to increase capacity. As previously mentioned, the City of Norman has initiated a policy of including a safety factor of 1.05 in projecting future maximum-day demands. This safety factor is equivalent to a minimum target reserve capacity of 5 percent and is applied to the maximum-day factor. Future maximum-day projections (the projected normal trend presented in Section 1.3) were based on the historic trend of 2.0.

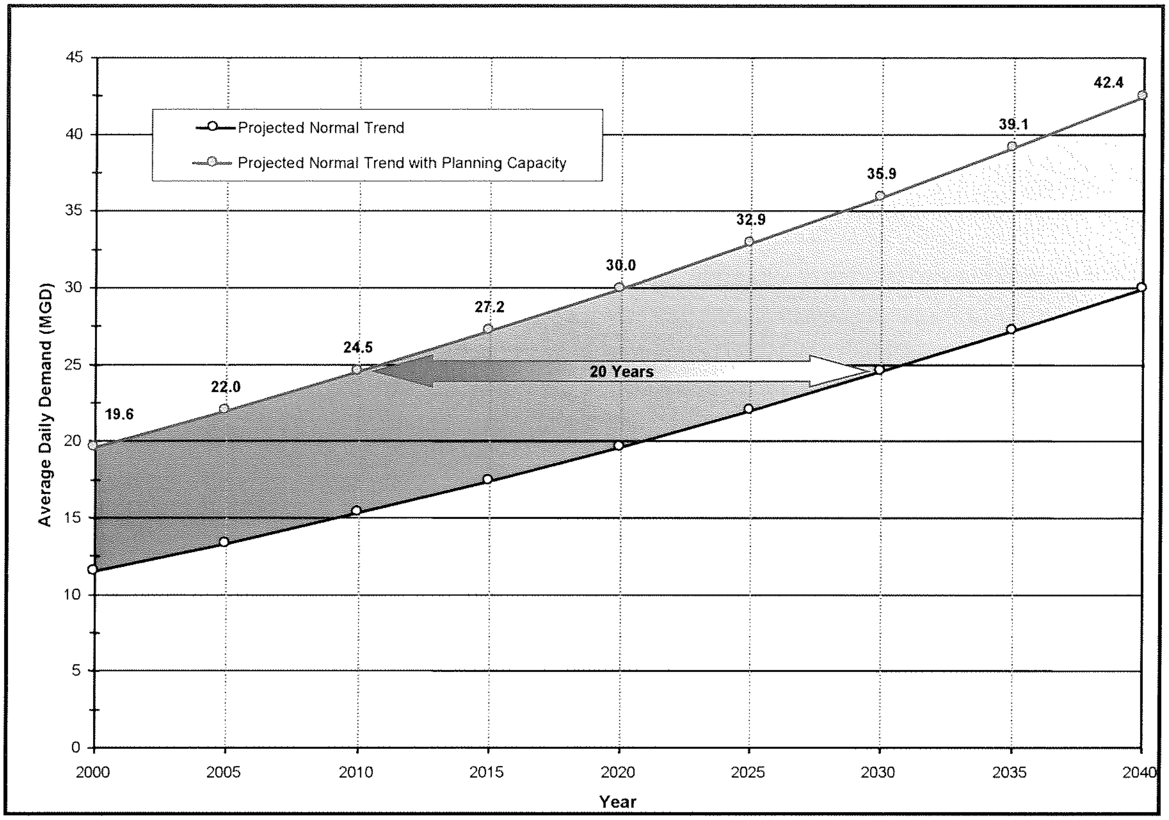


FIGURE 1-8
Projected Average-Daily Planning Capacity

In the late summer of 2000, the City procured an emergency supply service connection to an outside finished water supplier (Oklahoma City). With this considered, adopting a water production planning capacity with an assumed 5-year minimum implementation window (including design and construction of water treatment or production facilities and associated infrastructure) is recommended. The methodology for developing the water production planning capacity was the same as that for water resources, except the maximum-day demand (based on historic maximum day factor of 2.0) was transposed annually over a 5-year period. The maximum-day demand with a 5-year minimum planning capacity is equivalent to an average-maximum day factor of approximately 2.2 when compared to the projected normal average-daily demand trends presented in Section 1.3. Figure 1-9 depicts the maximum-day planning capacity.

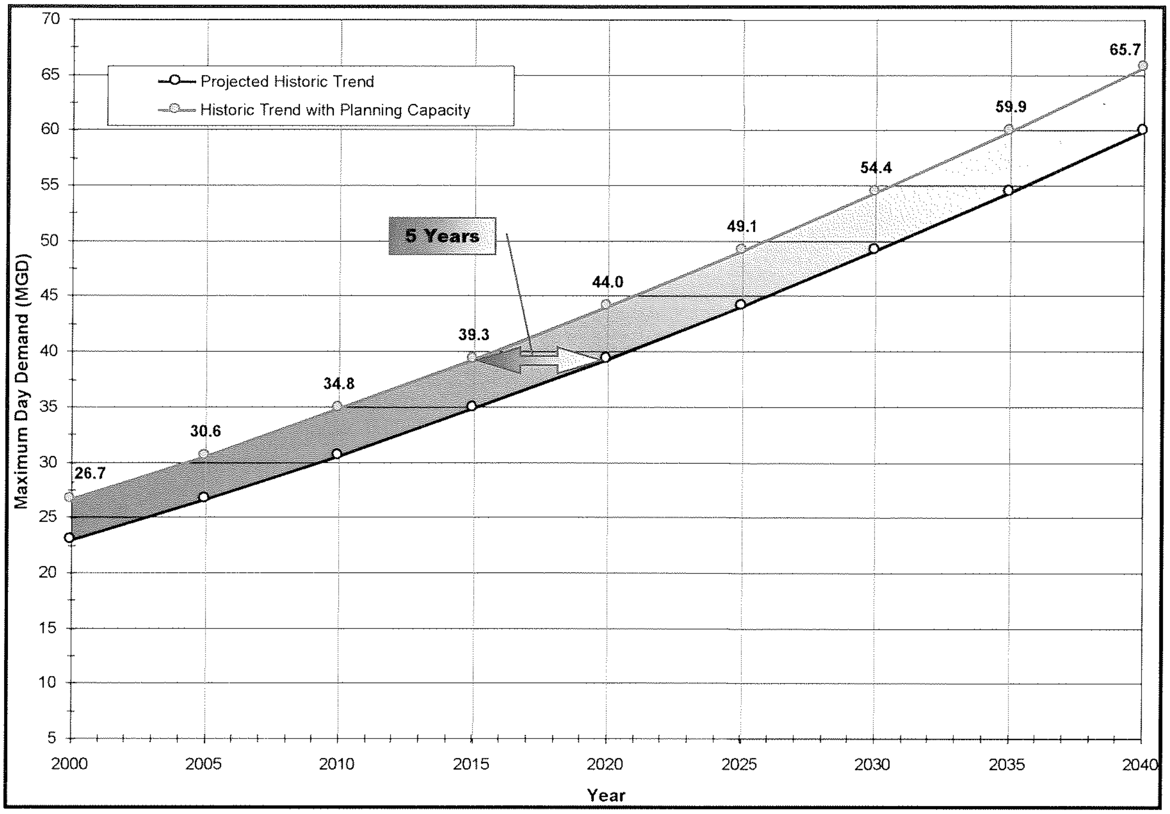


FIGURE 1-9
Projected Maximum-Day Planning Capacity

2. Existing System Assessment

2.1 Introduction

2.1.1 Overview

Water Resources

The City of Norman benefits from two water supply sources—the surface water of Lake Thunderbird and the groundwater of the Garber-Wellington Aquifer. These two sources have jointly met the demands of the City since the construction of Lake Thunderbird in 1965. Figure 2-1 depicts the existing groundwater and surface water subsystems.

The total supply from Lake Thunderbird is divided among the three municipalities of Midwest City, Del City, and the City of Norman. The City is allocated an annual-average of 8.4 million gallons per day (mgd) under its current contract. The quality of the water is generally good, classified as turbid, hard water. The City has exceeded its yearly allocation five times in the past nine years, suggesting that the increased population and demand is having a taxing effect on the system. The City currently operates the water treatment plant (WTP) to supply approximately 70 percent of the system's demand.

Groundwater from the Garber-Wellington Aquifer is used to supplement the surface water and supply approximately 30 percent of the City's demand. The Garber-Wellington Aquifer is a large aquifer formed by intermittent sandstone and shale layers. The shale layers act as confining strata in several areas, creating shallow, medium, and deep aquifers that sometimes act independently. Annual well production has generally been increasing to the current level of about 3.0 mgd. The quality of the water has been good, with only a few, minor violations over the historical record.

Water Treatment and Production

Surface water is taken from Lake Thunderbird and treated at the WTP and groundwater is pumped from the Garber-Wellington Aquifer to meet the demands of the City. The City uses Lake Thunderbird to meet 70 percent of the annual-average demand to maintain withdrawal from the lake within their allocation. Historically, the annual-average and maximum-day demands have risen for the overall system, as well as for the surface and groundwater systems independently. The historic annual-average demand supplied by Lake Thunderbird and the WTP is about 8.5 mgd. In addition, the historical annual-average demand produced by the wellfield is 2.4 mgd. However, these historical values are rising due to increasing demand.

The WTP utilizes a series of processes to meet current U.S. Environmental Protection Agency (EPA) regulations and produce safe drinking water. The processes include upflow clarifiers, recarbonation basins, mixed- and dual-media filters, and disinfection. The plant is maintained in excellent condition. The groundwater is pumped directly to the distribution system, with no treatment currently being provided. The wells also have a record of excellent maintenance.

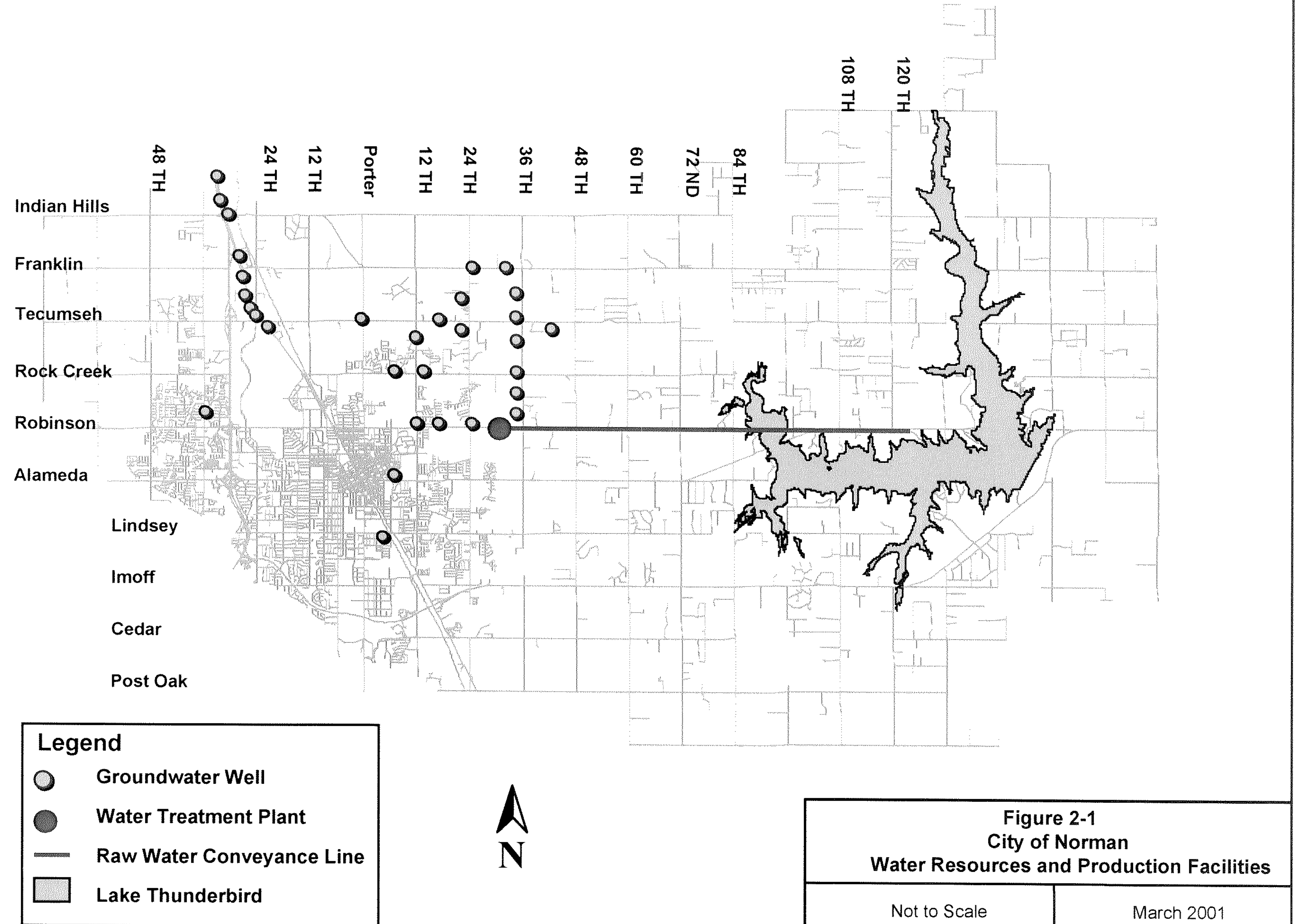


Figure 2-1
City of Norman
Water Resources and Production Facilities

Not to Scale	March 2001

Safe Drinking Water Act Amendments

The City will be responsible for compliance with all regulations passed by EPA, which may require capital improvements and/or changes in operational strategy. Although pending regulations may not be finalized for some time (2 to 3 years) and additional time will be allowed to upgrade facilities or change operating procedures to comply with the regulations, it is necessary to plan for the potential impacts now. After reviewing water quality data from the WTP and groundwater wells, it appears that the City will have the most difficulty in complying with the impacts of the Stage 1 Disinfectants/Disinfection Byproducts Rule (Stage 1 D/DBP Rule). The Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), the Groundwater Rule (GWR), and the Arsenic Rule may also have significant impacts. However, these rules are currently in draft form and are under discussion and review. Therefore, changes in the preliminary rules could greatly affect system modifications. Other regulations may also have impacts.

The Stage 1 D/DBP Rule limits residuals for disinfectants in the water supply, sets Maximum Contaminant Levels (MCL) for disinfectant byproducts (DBP) precursors, and defines treatment techniques for additional DBP precursors. From a cursory review of available data, it does not appear that limits to total trihalomethanes (TTHM) will have an impact on the plant as the measured levels are below the proposed MCL. However, with regard to haloacetic acids (HAA5), not enough data is present to estimate the potential impacts of the new MCL. HAA5 refers to five of the nine known haloacetic acids: mono-, di-, and tri-chloroacetic acids and mono- and di-bromoacetic acids. Treatment techniques using enhanced coagulation or enhanced softening may be required for the removal of DBP precursors unless the City meets certain criteria. At this time, it does not appear they will meet the avoidance criteria. Therefore, these treatment techniques will be large Stage 1 D/DBPR hurdles for the City, should they be required.

The LT2ESWTR and GWR are still in the development stages, and provisions are not yet well defined. However, it is important to note that these may have significant effects on the water system. The LT2ESWTR will attempt to provide additional microbial inactivation and is not scheduled for finalization until May 2002. The GWR may require disinfection of groundwater at the well sites prior to the distribution system.

Potential changes in the arsenic rule may also pose problems to the current operation of the wellfield. Several wells may not be in compliance with a new MCL, depending on the level of the MCL. As this rule is finalized, attention must be given to the wellfield to determine any necessary actions to comply with the rule.

Regulations governing specific contaminants such as radon, sulfate, and other radionuclides may also require changes to the current system at the time they are finalized.

2.1.2 Existing System Assessment Organization

As part of the Strategic Water Supply Plan, Section 2, Existing System Assessment, evaluates the City's existing water resources and treatment subsystems. Provided herein is information pertinent to the City's existing surface water and groundwater resources and associated WTP and wellfield. Additionally, this section provides a regulatory update to the Safe Drinking Water Act (SDWA) and evaluates the City's compliance status.

Section 2.2 presents the evaluation of the water resources currently used by the City—Lake Thunderbird and the Garber-Wellington Aquifer. This includes an analysis of the system including safe yield estimates.

Section 2.3 evaluates the City's existing water treatment and production facilities. This includes evaluation of the treatment processes, capacity, condition, and operation of the WTP and groundwater wells.

Section 2.4 presents an overview of the SDWA regulations and related water system compliance issues. A discussion of potential impacts of current and anticipated water quality regulations is provided.

2.2 Water Resources

2.2.1 General

The City of Norman currently utilizes a combined surface water and groundwater system to provide an adequate, high-quality water supply to its municipal and industrial users. The groundwater wellfield consists of 31 wells pumping water from the Garber-Wellington Aquifer. Groundwater currently is pumped from the wells directly to the distribution system via pipeline with no treatment required. Surface water is supplied by the Little River and Hog Creek watersheds, which are impounded to form Lake Thunderbird. Water is routed to the WTP to enhance water quality and meet all SDWA regulatory standards prior to distribution.

This section presents the findings of the existing supply and treatment system including condition, capability, and usage assessment.

2.2.2 Lake Thunderbird

Water Supply Allocation

The Bureau of Reclamation constructed Lake Thunderbird Reservoir in 1965 on the Little River nearly 13 miles east of Norman, Oklahoma. It was designed as a multi-use reservoir for municipal and industrial demands, flood control, fish and wildlife preservation, and recreation. The water supply was intended to meet the municipal and industrial demands of Midwest City, Del City, and the City of Norman. The reservoir is impounded by Norman Dam, which includes an outlet works and spillway. A raw water pump station is located on the north shore to allow for delivery of water to the referenced contracting municipalities. A 33-inch-diameter pipeline that reduces to a 30-inch-diameter pipeline provides raw water conveyance to the City WTP. A 33-inch-diameter pipeline also transports water to a re-lift pumping station, where flow is diverted to Midwest City and Del City. From the re-lift station, a 30-inch-diameter line carries water to Midwest City; and 21-inch- and 18-inch-diameter pipelines divert water to Del City.

Lake Thunderbird, similar to other water supply reservoirs, is divided into a series of pools whose capacities are intended for various purposes. These include flood control, conservation storage, and inactive and dead storage zones. There is also a surcharge pool that is intended to store additional water in the case of an extreme event. This surcharge storage pool is not regularly maintained for water supply usage. Table 2-1 outlines the initial capacities of each pool within Lake Thunderbird as well as the top of pool elevations above mean sea level.

TABLE 2-1
Lake Thunderbird Storage Levels

Pool	Volume (ac-ft)	Elevation (ft)
Surcharge	218,900	1064.7
Flood Control	76,600	1049.4
Conservation Storage	106,000	1039.0
Inactive Storage	12,400	1010.0
Dead Storage	1,200	997.0

The reservoir is operated by the Central Oklahoma Master Conservancy District (COMCD). Each of the three municipalities is under contract for specific allocation of the available annual supply. Currently, the City is allocated 43.8 percent of the supply, with allocations to Midwest City and Del City of 40.4 and 15.8 percent, respectively. The maximum-annual yield of Lake Thunderbird is 21,600 acre-feet (ac-ft) per year (or 19.4 mgd). Therefore, under the current contract, the City is allocated 8.4 mgd on an annual-average basis. Annual allotments not used in one year by the City may not be carried over to the following year. Also, additional water may be purchased on an as-negotiated basis, provided surplus water is available in the reservoir.

Historic Water Use

Since 1965, Lake Thunderbird has supplied water to the City of Norman. Although the total volume of water received has varied due to demand conditions, the City has contracted to receive an annual-average of 8.4 mgd since the lake's inception. The steady increase in population over the past thirty-five years has directly increased the demand, causing the City to exceed its allotment on several occasions. Figure 2-2, which shows the annual-average volume withdrawn from Lake Thunderbird since 1975 compared to the allotted 8.4 mgd, illustrates this overall increasing trend in demand. This data was taken from the COMCD and also compared with the inflows at the WTP for validity.

The data shown on Figure 2-2 illustrates a common trend that the volume of water drawn from Lake Thunderbird has increased significantly. Since 1990, the City has exceeded its allotment from the lake five times. However, neither Midwest City nor Del City is currently utilizing their full allotment of water. The City uses Lake Thunderbird to supply approximately 70 percent of the average-annual demand. This is an effort to prevent exceeding the allocated 8.4 mgd. The remaining 30 percent of the water is supplied via groundwater wells.

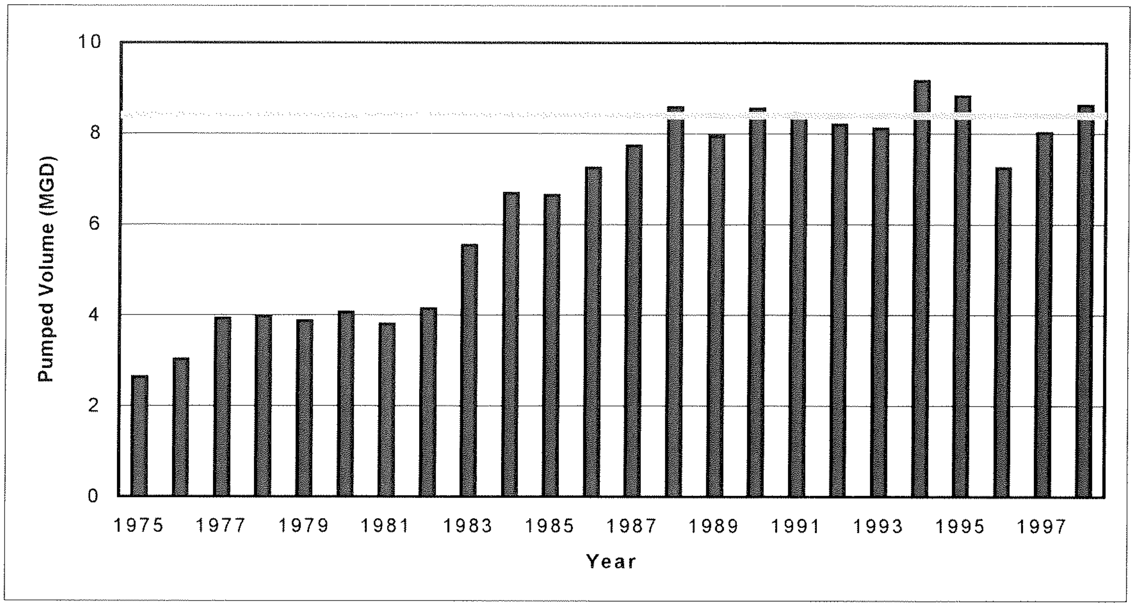


FIGURE 2-2
Historic Water Consumption From Lake Thunderbird

Water Quality

A series of factors contribute to the water quality at Lake Thunderbird. The surrounding environment and the aquatic environment have direct effects on water quality, and directly influence the raw water quality at the WTP and potentially effect the finished water quality. In general, raw water quality from Lake Thunderbird is influenced by chemicals, debris, organisms, nutrients, colloidal particles, and metals naturally occurring or resulting from agricultural practices and urbanization of the watershed.

A series of parameters of raw water are measured for comparison with finished water parameters, and to ensure that the existing treatment process will provide reliable, safe water to the public. This can also alert the WTP staff in the event of a peak in the concentration of a contaminant in the influent flow. Daily operating logs from June 1993 to June 1998 were used to characterize the raw water flow for the following parameters.

- Temperature
- pH
- Alkalinity
- Hardness
- Turbidity
- Total Organic Carbon (TOC)

Monthly averages of the above water quality elements for the five-year historic record are provided in Appendix B. A summary of the data set is shown in Table 2-2, with a discussion of the identified items following.

TABLE 2-2
Lake Thunderbird Raw Water Quality Summary

Characteristic	Minimum [a]	Average [a]	Maximum [a]
Temperature, celcius	2	17.5	29
PH	7.67	8.05	8.4
Alkalinity (Total)	103 mg/L	147 mg/L	184 mg/L
Total Hardness	104 mg/L	181 mg/L	225 mg/L
Calcium Hardness	71 mg/L	142.6 mg/L	196 mg/L
Magnesium Hardness	2.5 mg/L	38.5 mg/L	116 mg/L
Turbidity	5 NTU	12.3 NTU	49 NTU
TOC[b]		6.6 mg/L	

Notes:
[a] Minimum, average, and maximum values of monthly averages of water quality data from January 1995 to June 1998.
[b] Data represents one sampling event from March 11,1999.

The temperature of the lake water is dependent on the climate conditions surrounding the lake. In general, variations in temperature can cause thermal stratification and subsequent de-stratification, which can significantly alter chemical feed requirements and reaction rates at the plant. Stratification occurs where the bottom layer (hypolimnion) becomes oxygen deficient. Such a phenomenon can result in objectionable taste and odors produced by the hypolimnion. This phenomenon is mitigated through two practices. First, the lake is artificially mixed to prevent stratification from occurring. This is achieved with an air injection system near the dam. Secondly, the COMCD also has the ability to alter the intake withdrawal depths to aid in circulation of the water. These methods can alleviate thermal stratification and the effects of de-stratification on the water chemistry.

Surface water typically has a pH in the range of 6.5 to 8.5, which is also the optimum range for natural biota. The pH of the raw water is largely influenced by the alkalinity of the water, a measure of the water's capacity to neutralize acids. In natural waters, alkalinity is related to bicarbonate, carbonate, and hydroxide concentrations. Similar to temperature, pH also affects reaction rates. As such, the WTP must provide pH adjustment for different treatment processes. Lime addition, during the softening process, raises the pH of the water to approximately 10.5 to 11, which causes precipitation of the carbonate form of calcium and magnesium. Further discussion of water hardness and lime softening is provided below.

Water hardness is defined as the amount of divalent metallic cations in the water and is expressed in milligrams per liter (mg/L) as calcium carbonate ($CaCO_3$). Several divalent metallic cations contribute to water hardness; however, the principle contributors to hardness, in most cases, are calcium and magnesium. The level of hardness is usually classified as follows.

- Soft — 0 to 75 mg/L as $CaCO_3$
- Moderate — 75 to 150 mg/L as $CaCO_3$
- Hard — 150 to 300 mg/L as $CaCO_3$
- Very Hard — Above 300 mg/L as $CaCO_3$

Based on the average-total hardness of the raw water and the above classifications, Lake Thunderbird raw water is considered moderately hard water. The WTP currently softens the water (removes hardness) through the practice of lime softening. It should be noted that hard water is not currently known to adversely affect human health in any significant manner. However, water hardness can cause scaling problems, which affects the WTP and distribution system in addition to the consumers or industries served. Furthermore, softening, especially lime softening, has several additional benefits, such as removal of heavy metals, organics, and suspended solids.

Based on the average turbidity, Lake Thunderbird raw water is classified as turbid, i.e. water with turbidity greater than 10 nephelometric turbidity units (NTU). Turbidity is caused by colloidal particles suspended in the water. Several treatment issues are associated with turbidity. First, turbidity can include microorganisms, such as bacteria and viruses, that are suspended in the water. Therefore, treatment techniques and water quality regulations correlate turbidity removal with microorganism removal. Furthermore, colloidal particles can be organic in nature. Organic constituents in the water are often precursors to DBP. Control of DBP is a primary focus of future water quality regulations. Finally, turbidity is also associated with the aesthetic quality of the water. Specifically, colloidal particles can include decaying organic material that can cause taste and odor problems. Also, colloidal particles contribute to the natural color of the raw water. Therefore, public opinion and possibly acceptance of both raw and treated water is influenced by turbidity. At the City's WTP, clarification, lime softening, and filtration treatment practices are currently used to remove the colloidal particles. It should be noted that turbidity removal alone is not sufficient for microbial protection. Chloramines are applied at the WTP for both primary (microbial inactivation) and secondary (residual maintenance) disinfection.

TOC removal is critical for the control of DBPs. As previously mentioned, certain organic compounds in the water are precursors to DBPs. Therefore, to qualify the raw water TOC level, consider the anticipated TOC removal requirements under the proposed D/DBP Rule. Basically, the rule sets 4.0 mg/L TOC concentration in the raw water (prior to any treatment) as a trigger for specific treatment requirements, i.e. enhanced coagulation, enhanced softening, or activated carbon. It should be noted there are other specific criteria associated with the rule, which will be outlined in Section 2.4. The data set for TOC includes only one sample, and is therefore difficult to speculate on the average TOC levels. Development of a comprehensive TOC profile through the WTP process train is recommended before formulating and process improvements.

In conclusion, Lake Thunderbird raw water can be characterized, based on generalities, as turbid, moderately hard water. As such, the WTP provides softening and filtration. Because turbidity removal is correlated with microbial removal, turbidity removal along with disinfection ensures microbial inactivation and removal.

2.2.3 Garber-Wellington Aquifer (Central Oklahoma Aquifer)

General

A significant quantity of the water supply used to meet the demand of the City is obtained from 31 City-owned deep wells that tap the Garber-Wellington Aquifer (local name, also termed the Central Oklahoma Aquifer). About 88 percent of City residents are connected to the municipal system. The remaining 12 percent utilize privately owned shallow wells for water supply.

Geology of the Aquifer

Underlying the Hennessey Shale, the Garber-Wellington Aquifer occurs within the permeable stratigraphy of the Lower Permian-age Wellington Formation and the Garber Sandstone, as depicted in Table 2-3. These rocks are between 280 and 290 million years old. The formations occur in a westward sloping homocline with a dip of 30 to 35 feet per mile. The combined thickness of the two formations ranges from 800 to 1,000 feet (Wood and Burton, 1968). The confining unit, Hennessey Shale, outcrops west of Lake Thunderbird, as illustrated in Figure 2-3. As such, the area east of this outcrop is considered the unconfined, recharge zone of the aquifer.

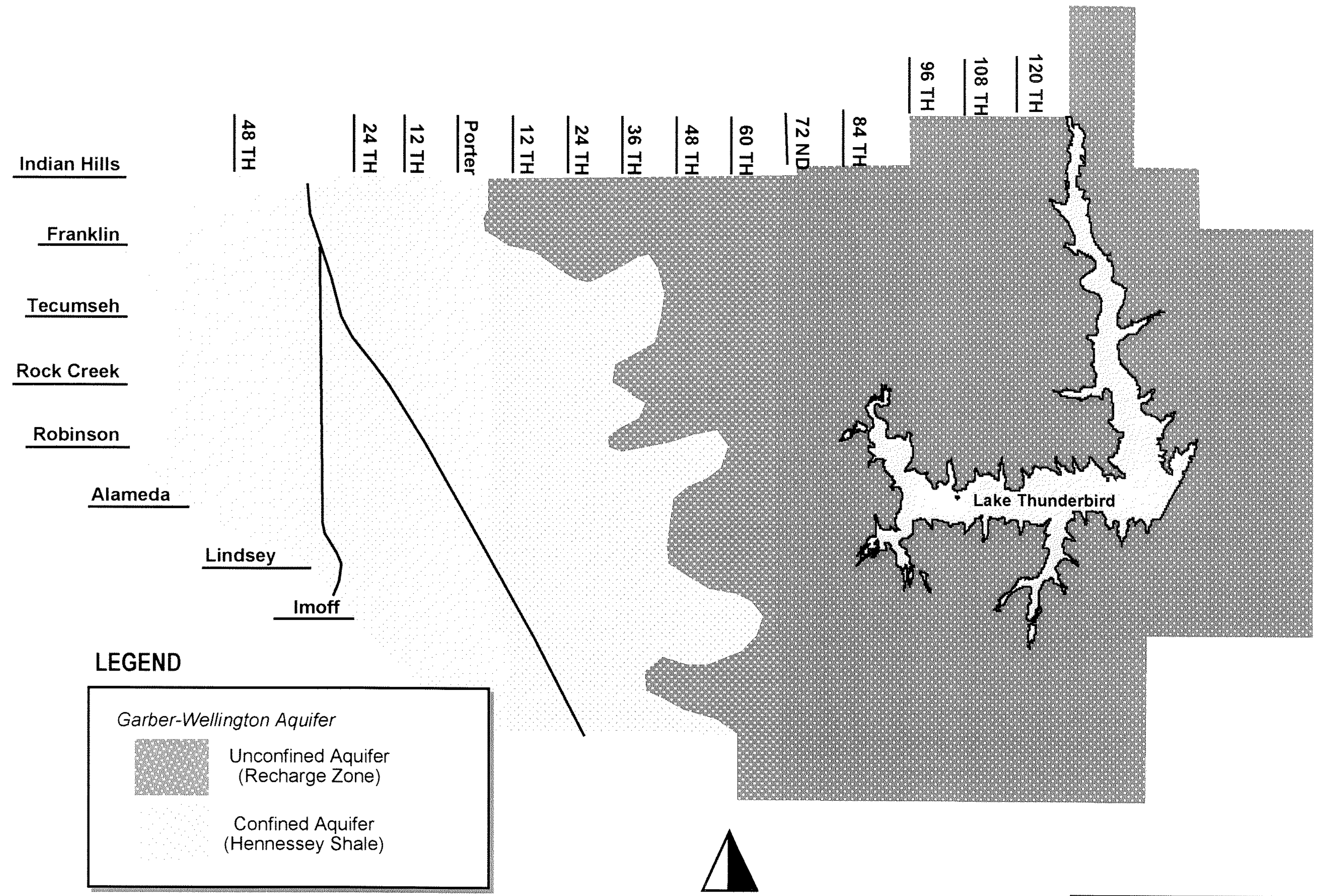
The stratigraphy of both the Wellington Formation and the Garber Sandstone is quite complex. The Wellington Formation is a red, massive cross-bedded sandstone with irregularly interbedded shale. The sandstone is generally fine-grained with wide variations in porosity and permeability. The Garber Sandstone is a red, massive cross-bedded sandstone and siltstone both interbedded and interfingered with shale. It is also fine-grained and has wide variations in porosity and permeability. The interbedding and interfingering between the sandstones and shale makes the aquifer very inhomogeneous and causes wide-spread variations in hydraulic properties. Sandstone beds or units within wells range from 0.5- to 50-feet in thickness. The sandstones are commonly poorly cemented and somewhat friable. The cements are red clays and some are carbonates (calcite) as well as other rare minerals. The sandstones are primary continentals with some marine influence. Channel fill deposits are common and give the units an even greater inhomogeneity.

Aquifer Hydraulic Properties

The hydraulic properties of most significance are the hydraulic conductivity (permeability), transmissivity, specific yield (where the aquifer is unconfined), storativity (where the aquifer is confined), and leakance. Hydraulic conductivity is nearly equivalent to permeability. It is defined as the ability of a rock or sediment to transmit water. The transmissivity of an aquifer is the ability of an aquifer to transmit water and is equal to the aquifer hydraulic conductivity times the thickness. The specific yield of an unconfined aquifer is equal to the porosity minus the specific retention, which is the quantity of water the aquifer will not transmit because of surface reactions or non-connected pores. The storativity of a confined or semi-confined aquifer is equal to the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

Table 2-3
Geologic Units Exposed in Cleveland and Oklahoma Counties (from Wood and Burton, 1968)

System	Series	Strategraphic Unit	Thickness (Feet)	Description and Distribution	Water-Bearing Properties
QUATERNARY	Recent	Dune sand	0-20	Fine to coarse-grained wind-blown sand. Con-sists chiefly of subrounded quartz grains. Forms a thin mantle or hummocky surface that obscures older rocks. Most excessive deposits on north side of North Canadian River near Lake Overholser.	Moderately to highy permeable, but mostlyabove the water table and saturated only locally. Where saturated, yields water readily to domestic or stock wells, but supply may not be permanent. Water most likely to occur in this unit where underlain by poorly permeable redbeds. Provides infiltration areas for recharge to underlying rocks.
	Pleistocene and Recent	Aluvium	0-70	Unconsolidated and interfingering lenses of sand, silt, clay, and gravel in the flood plains of the principal streams.	Moderately permeable. Yields small to moderate quantities of water to wells in valleys of larger streams. Water is very hard, but suitable for most uses, unless contaminated by industrial wastes or oil-field brines.
		Terrace deposits	0-100	Unconsolidated and interfingering lenses of sand, silt, gravel, and clay that occur at one or more levels above the flood plains of the principal streams.	Moderately permeable. Locally above the water table and not saturated. Where deposits have sufficient saturated thickness, they are capable of yielding moderate quantities of water to wells. Water is moderately hard to very hard, but less mineralized than water in other aquifers. Suitable for most uses unless contaminated by oil-field brines.
PERMIAN	Lower Permian	Chickasha Formation and Duncan Sandstone	200 +/-	Beds of reddish-brown sandstone, siltstone, shale, and siltstone conglomerate. Individual beds of sandstone highly cross-bedded and well cemented in western part of area between Canadian and North Canadian Rivers.	Possibly permeable. Tapped by a few small-capacity wells for domestic or stock use. Water is hard and in places highy mineralized.
		Hennessey Shale	700	Deep-end clay shale containing thin beds of red sandstone and white or greenish bands of sandy or limy shale. Forms relatively flat to gently rolling grass-covered prairies.	Poorly permeable. Yields meager quantities of very hard, moderately to highly mineralized water to shallow domestic and stock wells. In places water contains large amounts of sulfate.
		Garber Sandstone	500+/-	Deep-red to reddish orange, massive and cross-bedded fine-grained sandstone interbedded with and iinterfingered with red shale and siltstone.	Poorly to moderately permeable. Important source of ground water in Cleveland and Oklahoma Counties. Yields small to moderate qualtities of water to deep wells; heavily pumped for industrial and municipal uses in the Norman and Midwest City areas. Water from shallow wells hard to very hard; water from deep wells moderately hard to soft. Lower part contains water too salty for domestic and most industrial uses.
		Wellington Formation	500+/-	Deep-red to reddish -orange, massive and cross-bedded fine-grained sandstone, irregulraly imbedded with red, purple, maroon, and gray shale. Base of formation not exposed in the area.	



Reference: ACOG

Figure 2-3
Garber-Wellington Aquifer
Confined and Unconfined Aquifer

The variable nature of the lithology within the Garber-Wellington Aquifer causes wide ranges in the local values for hydraulic conductivity. Some actual measurements of hydraulic conductivity based on aquifer performance tests yield values from 20- to 36-gallons per day per square foot (gpd/ft^2) (Wood and Burton, 1968). Since shale and sandstones are contained within the aquifer and the test results are from averages across given sections of the aquifer, the actual range in hydraulic conductivity is from about 5- to 100-gpd/ft^2 (Ward and Burton, 1968).

Transmissivity values for the Garber-Wellington Aquifer in the region of investigation range from 1,000- to 7,000-gpd/ft (Wood and Burton, 1968). An estimated transmissivity at the City wellfield is about 2,500-gpd/ft (Simpson, 1991). Since transmissivity is equal to the aquifer thickness times the horizontal hydraulic conductivity, great variation in calculated values from standard aquifer performance tests is common because of the interbedded nature of the rock units and the discontinuous nature of sandstone beds. This large variation causes well yields to vary on a spatial basis.

The specific yield of the aquifer is very difficult to determine because the value tends to increase during a standard aquifer test as water drains from the top of the aquifer. The inhomogeneous nature of the aquifer causes it to behave like a confined system and transition to an unconfined aquifer. No accurate values have been determined for specific yield. Because the percentage of sandstone within the aquifer at any given location affects the specific yield, values could range from about 0.001 to 0.05 (Simpson, 1991).

Storativity values have been determined from aquifer tests, and values range from $1x10^{-4}$ to $3x10^{-4}$ (Wood and Burton, 1968). The storativity values will tend to be higher in the transition zone where the aquifer becomes confined because there is some influence of vertical drainage within the aquifer in this zone. Therefore, a full range in values is probably $1x10^{-5}$ to $1x10^{-3}$ (Simpson, 1991).

The leakance of the Garber-Wellington Aquifer has not been directly measured. Since the confining shale, both bottom and top, are virtually impervious, the boundary leakance for the aquifer should be an extremely small number less than $1x10^{-7}$ gpd/ft^3. Leakance values obtained during aquifer testing may not be accurate because of the internal flow pattern within the aquifer as caused by its inhomogeneous nature.

Aquifer Water Levels and Gradients

Water levels within the Garber-Wellington Aquifer are affected by climate conditions in the unconfined zone and primarily by pumpage in the confined area. There is a direct correspondence between rainfall and water level in the eastern part of the area where the aquifer is unconfined. The water levels are high during wet periods, but they decline during dry periods due to evaporation and subsurface flow to streams. The potentiometric surface of the aquifer has changed significantly from 1970 to 1990, as shown on Figures 2-4 and 2-5. The drawdown of potentiometric pressure is evidenced by a few hundred feet of drawdown in the centers of pumpage, particularly beneath the confined parts of the aquifer (western area).

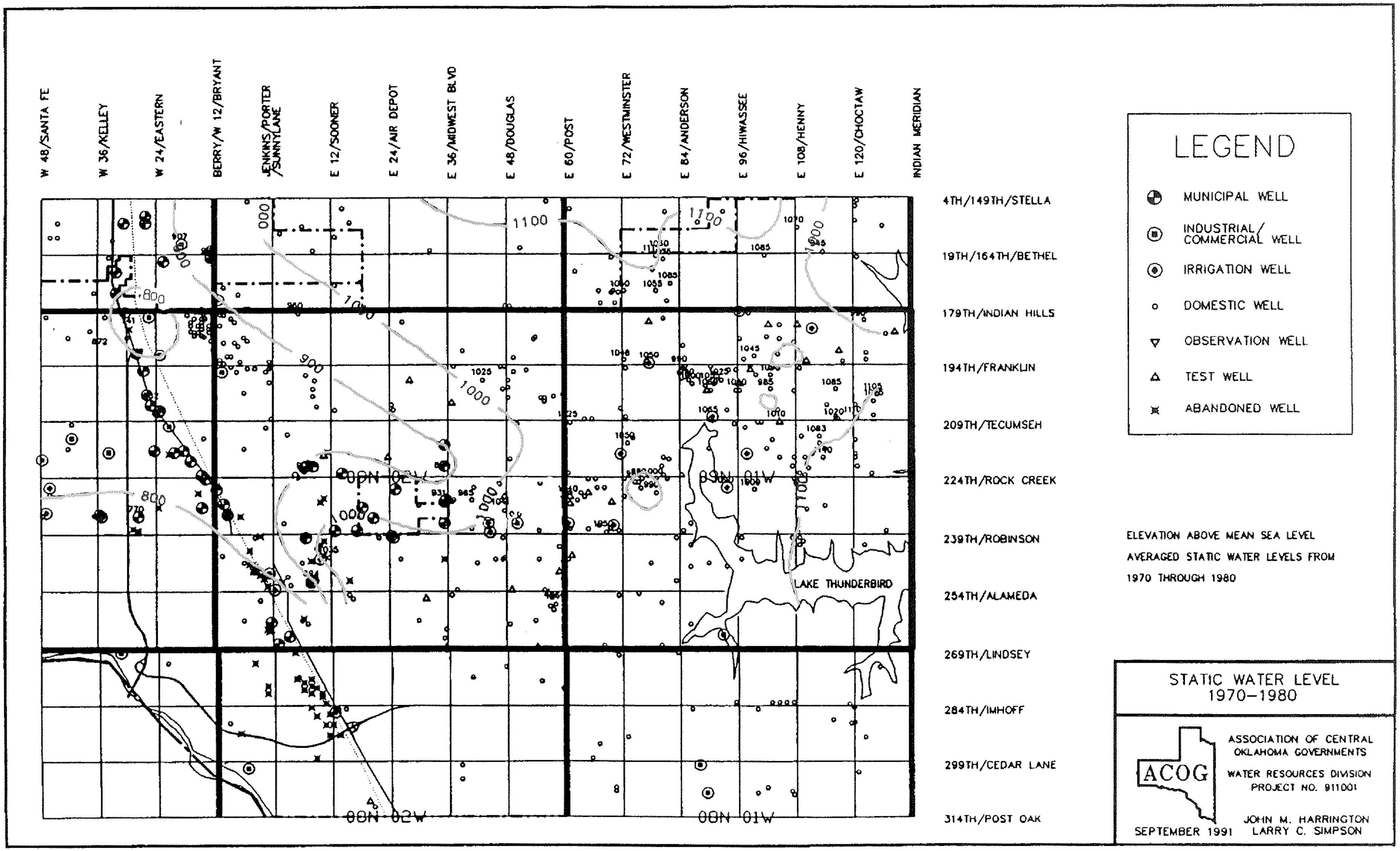


FIGURE 2-4
Garber-Wellington Aquifer
Static Water Level, 1970-1980

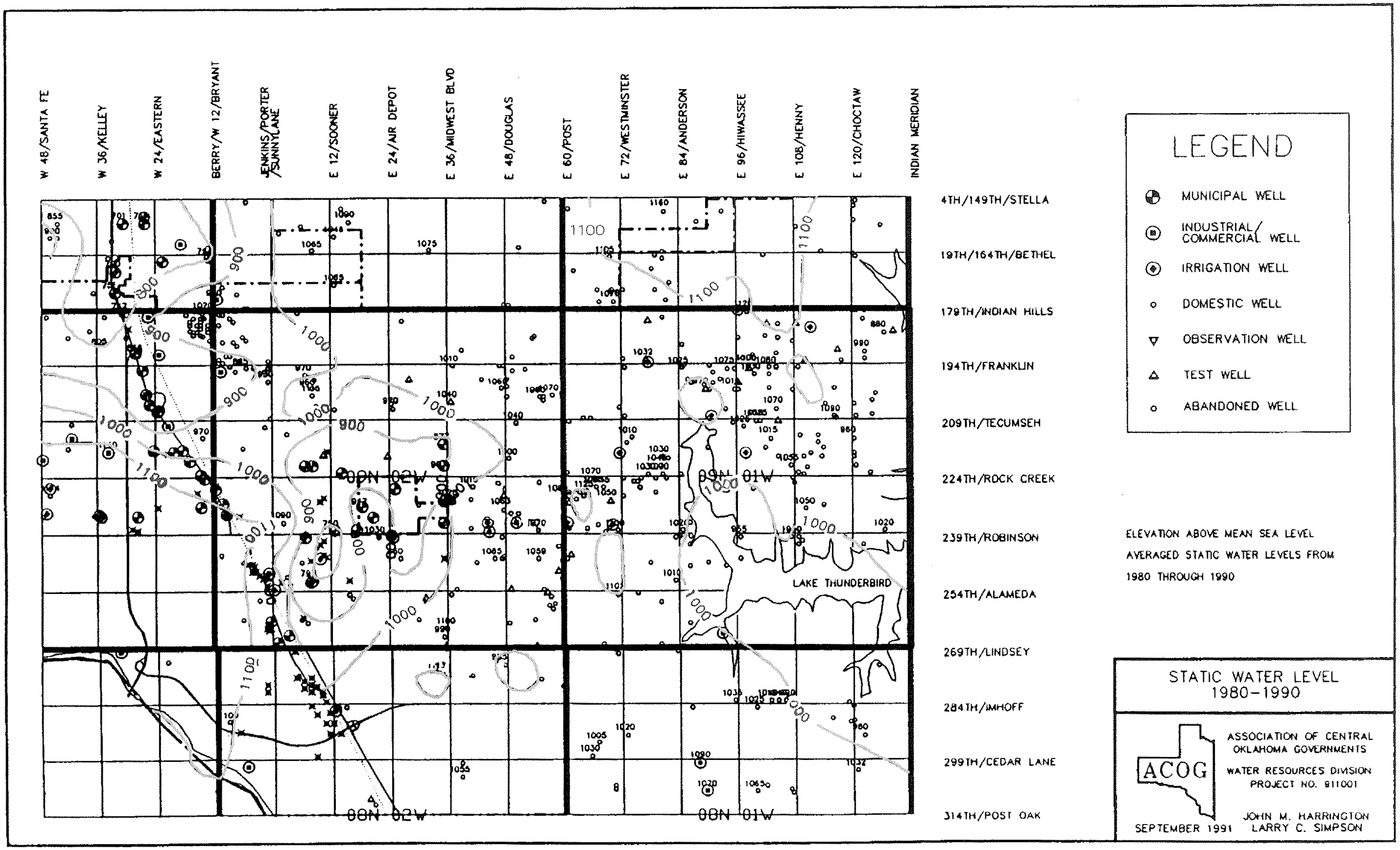


FIGURE 2-5
Garber-Wellington Aquifer
Static Water Level, 1980-1990

The potentiometric gradient through the aquifer from the recharge area where the formations outcrop to the confined area is quite important. The original pre-development slope is about 50 feet per mile, taken from Figure 2-4. The pumping-induced drawdown has locally altered the gradient within the aquifer, but has not greatly affected the overall horizontal flow rate from the recharge area into the confined part of the aquifer.

Aquifer Recharge

The annual recharge rate for the Garber-Wellington Aquifer in the Cleveland County area is estimated to be about 5 percent of the annual rainfall. This percentage yields recharge rates of about 90 ac-ft per square mile and a total of about 72,000 ac-ft per year (or 65 mgd) for the entire aquifer (Wood and Burton, 1968).

There is a very important concept that must be considered when using the annual recharge rate in an assessment of yield potential from the confined part of the aquifer. This concept follows: "Because of the relatively low transmissibility (transmissivity) of the aquifer and the low gradients from the outcrop area westward toward the main centers of pumping, it may not be possible for the aquifer to transmit water from the recharge areas toward the pumping centers at the estimated rate of recharge" (Wood and Burton, 1968). Only a certain percentage of the water that recharges the aquifer in the east moves through the aquifer to the west.

A preliminary analysis of flow into the western area (confined) can be made by using a form of Darcy's Law, which is:

(1) $Q = TIL$

where:
Q = the flow rate in gallons per day
T = transmissivity, in gpd/ft
I = hydraulic gradient, in ft/mile
L = a length of the aquifer through which flow moves into the area, in miles

Based on a transmissivity of 2,500 gpd/ft, a hydraulic gradient of 50 feet per mile, and a length of 10 miles, the horizontal recharge rate into the aquifer in the area where it is pumped is about 1.25 mgd. Even if the length of the recharge area is increased to 20 miles, the recharge rate would still be only 2.5 mgd.

Aquifer Water Quality

Water within the Garber-Wellington Aquifer is density stratified with freshwater in the upper layers and saline water at the base. The thickness of freshwater in the aquifer is mapped on Figure 2-6. With the northeast portion of the study reach containing the thickest freshwater interval (500 to 700 ft.), the thickness of fresh water decreases from east to west moving away from the recharge area.

There are areas where the saline water has moved into the upper portion of the aquifer. Thinning of the freshwater thickness and upward movement of saline water is the direct result of pumping. The occurrence of saline water within the aquifer has a direct bearing on the sustainable yield of freshwater for public water supply.

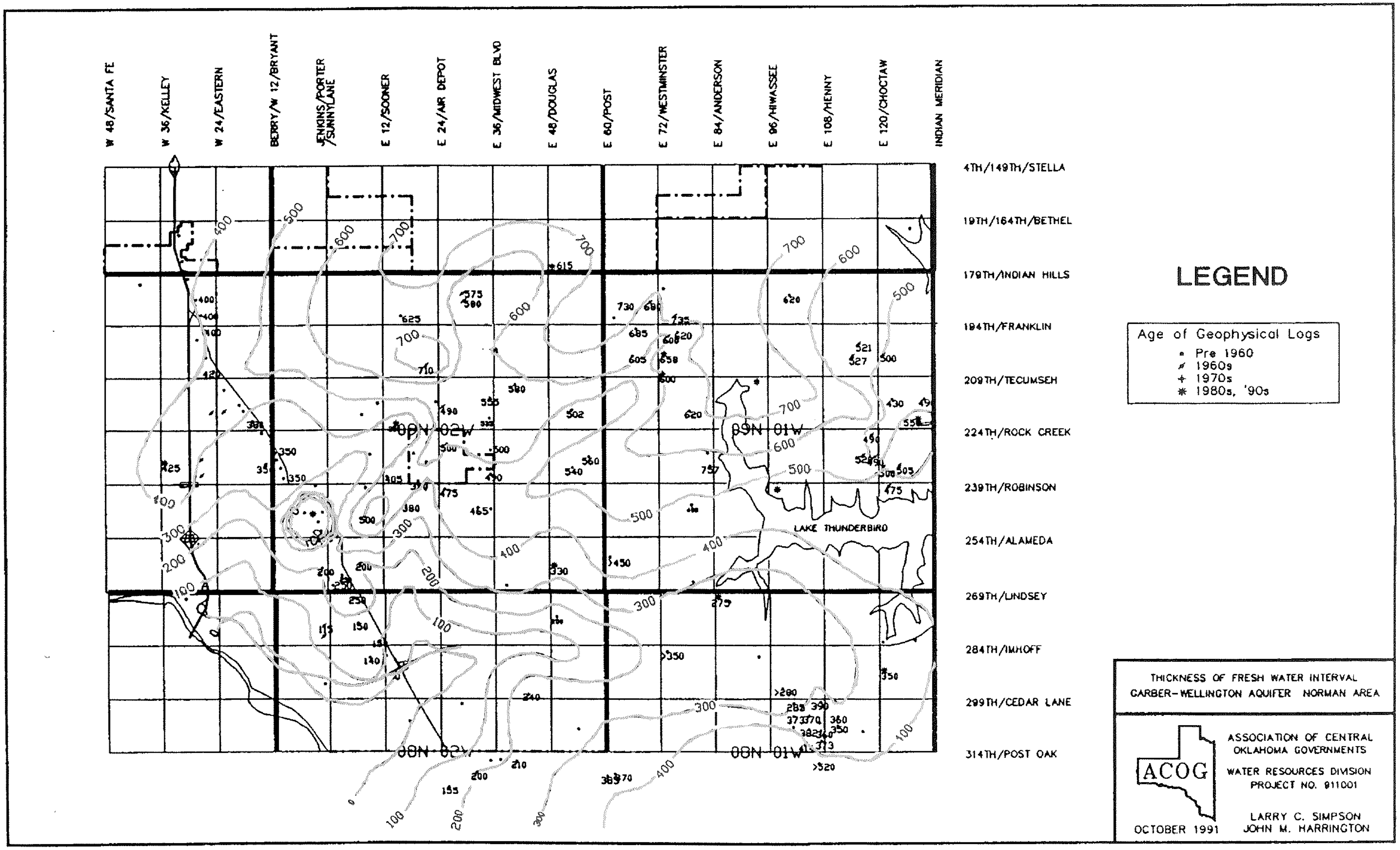


FIGURE 2-6
Garber-Wellington Aquifer
Thickness of Fresh Water Interval

The quality of the produced groundwater has been fairly consistent over time, based on a review of information available from 1993 through 1998. Trends in standard water quality parameters measured by the City on a routine basis are presented in Table 2-4.

These data characterizing standard water quality parameters are based on an average of the samples collected from 1993 through 1998. As shown, the data set reveals only two minor violations with Oklahoma Department of Environmental Quality (ODEQ)/EPA regulations. It is clear that the water produced from the Garber-Wellington Aquifer is of adequate quality for consumption.

Based on the data provided in Table 2-4 and the previous discussion on water hardness, the groundwater can be classified as soft to moderately hard water. Water hardness potentially causes scaling in the distribution system, which affects water system operation as well as consumers. However, water hardness is not currently associated with any significant adverse human health affects.

Conductivity of the groundwater is correlated with total dissolved solids (TDS). Groundwater naturally contains a number of different dissolved inorganic constituents, some of which contribute to the water's hardness and alkalinity. As previously mentioned, alkalinity is a measure of the water's capacity to neutralize acids. As such, alkalinity directly effects the pH of the water. The major anions are typically chloride, sulfate, carbonate, and bicarbonate. These major constituents constitute the bulk of the mineral matter contributing to TDS. In addition, there may be minor constituents present, including, but not limited to, iron, manganese, fluoride, and nitrate. Based on the data provided in Table 2-4, the groundwater has a TDS ranging from 240 to 370 mg/L. Groundwater, in general, is often classified based on TDS concentration in the water as follows:

- Fresh 0-1,000 mg/L TDS
- Brackish 1,000-10,000 mg/L TDS
- Saline 10,000 - 100,000 mg/L TDS
- Brine greater than 100,000 mg/L TDS

Considering the general classifications presented above, the groundwater is considered fresh water.

Another concern of groundwater quality is that of possible contamination with organic compounds. Contamination from organics may be due to commercial, industrial, and residential discharges, controlled or uncontrolled, of such compounds. These compounds can migrate through the ground, thereby contaminating the groundwater. Table 2-4 details the levels of some limited organics that were found. A detailed review of groundwater quality data (i.e. inorganic and organic constituents) relative to standards and regulations is provided in Section 2.4.

Naturally occurring radioactive compounds such as uranium, and gross alpha and beta activity exist in the shales of the Garber-Wellington Formation. For example, radium 226 and uranium are alpha emitters and radium 228 is a beta emitter. Although there is no current data from the City's wells, radionuclide data is available from monitoring wells on the Westwood Golf Course. The data, rather than provide an exact value, provides a range of values. As such, it is difficult to draw definitive conclusions. Nevertheless, considering

Table 2-4

Summary of Well Data [a] [b]

	pH	Total Alkalinity mg/L	Total Hardness mg/L	Calcium Hardness mg/L	Total Dissolved Solids (TDS) mg/L	Phenols	Arsenic µg/L	Barium mg/L	Chromium mg/L	Iron mg/L	Manganese mg/L	Selenium mg/L	Sulfate mg/L	Chloride mg/L	Flouride mg/L	Nitrate-Nitrite mg/L	Coliforms [b] per 100 mL
EPA Standard	6.5-8.5	[c]	[c]	[c]	500.0	[c]	50.0	2.00	0.10	0.30	0.05	0.05	250.0	250.0	2.00	10.00	5% of Samples
Well 1	8.1	239.9	134.5	51.5													
Well 2	8.1	239.3	89.7	43.8			5.0	0.17	0.08			0.02			0.67	0.21	
Well 3	8.0	246.0	106.6	60.9				0.19	0.07						0.42	0.37	
Well 4	8.5	191.4	95.1	32.2		<0.001	21.0	0.14	0.07	0.12	0.01	0.02	21.8	30.5	0.63	0.45	0
Well 5	7.9	291.2	78.6	28.2			2.0	0.25	0.07						0.70	0.27	
Well 6	8.3	314.2	84.7	32.9	370.0	<0.001	10.0	0.43	0.03	0.06	0.20	0.01	18.4	49.0	0.32	0.20	0
Well 7	8.4	190.7	62.2	32.3		<0.001	28.0	0.06	0.01	0.05	<0.01	0.03	44.2	10.0	0.70	0.18	0
Well 8	8.2	242.0	103.5	48.8	240.0	<0.001	3.0	0.24	0.02	0.05	0.04		24.7	12.5	0.27	0.44	0
Well 11	8.5	185.8	92.3	32.8	240.0	<0.001	35.0	0.13	0.03	0.04	0.02	0.01	18.4	12.0	0.95	0.30	0
Well 12	8.3	327.0	71.8	26.8		<0.001				0.04	0.02		7.3				<1
Well 13	7.8	255.9	134.5	45.8													
Well 14	8.3	258.0	106.7	31.5			27.0	0.13	0.04			0.02			0.90	0.44	
Well 15	8.2	241.2	115.8	65.7			20.0	0.23	0.03						0.26	0.50	
Well 16	8.5	257.6	66.0	38.7	290.0	<0.001	39.0	0.10	0.02	0.07	0.02	0.02	14.2	12.0	0.27	0.53	<1
Well 18	8.5	269.4	48.8	21.9	290.0	<0.001	20.0	0.07		0.06	<0.02	0.01	18.8	12.0	0.20	0.60	<1
Well 19	8.2	206.3	61.9	39.7		<0.001	15.0	0.34	0.01	0.34	0.02		15.2	16.0	0.15	0.64	0
Well 20	8.1	79.3	77.5	51.0		<0.001	4.0	0.98		0.06	<0.01		11.2	8.0	0.73	0.62	2
Well 21	8.2	115.0	72.5	40.8		<0.001	21.0	0.35		0.08	0.01		11.7	18.0	0.84	0.50	0
Well 23	8.2	282.8	47.4	14.9		<0.001	46.0	0.06	0.03	0.08	0.03	0.02	59.5	29.0	0.78	0.30	0
Well 24	8.4	145.0	78.0	30.0		<0.001				0.04	0.01		120.6	40.0	0.58		0
Well 25	8.3	223.4	70.7	35.7		<0.001			0.03	0.15	0.01	<0.01	15.4				<1
Well 31	8.6	238.0	102.1	54.3													
Well 32	8.5	231.4	115.4	60.4						0.29							

Note: [a] Average of samples from Jan 93 - Jun 98. Values reported as <1 indicate test positive samples that could not be replicated.

[b] Data represents total occurence from January 1993 to June 1998

[c] No regulatory limit

the reported values are close to MCL, it is likely there is no appreciable public health concern. Construction methods utilized by well drillers attempt to minimize the impacts of radionuclides on the pumped groundwater by selectively placing a blank screen across the shale zones encountered. Construction of new groundwater supply wells must be completed with this potential impact in mind.

It should be noted that the major focus of water quality regulations is microbial (contamination) inactivation and/or removal. The anticipated GWR, as discussed in Section 2.4.7, may require disinfection at all wellheads if protective barriers are not met. If this is the case with the City, a common facility or facilities may be required to collect the groundwater for disinfection. Further information is presented in Section 2.4. In addition to the GWR, the SWTR and the ESWTR will require groundwater that is under the direct influence of surface water to be treated. Specifically, groundwater under the direct influence of surface water will require filtration and disinfection, at a minimum. Additional discussion on regulatory compliance follows in Section 2.4.

Pumpage from the Aquifer

Pumping from the Garber-Wellington Aquifer has increased significantly over the last 10 years. Water pumped by the City was 289.7 million gallons (MG) (0.8 mgd) in 1990 and increased to 1,265.6 MG (3.5 mgd) in 1998, as depicted in Table 2-5.

TABLE 2-5
Summary of Annual Wellwater Production

Year	Total Water Production (MG/yr)	No. Of Wells Operated	Annual Average Water Production (mgd)	Water Produced per Well (gpm)
1990	290	21	0.8	26
1991	386	17	1.1	43
1992	278	21	0.8	25
1993	490	21	1.3	44
1994	367	20	1.0	35
1995	676	20	1.9	64
1996	1,034	21	2.8	94
1997	979	23	2.7	81
1998	1,266	23	3.5	105

A breakdown of pumping from the existing production wells in 1997 is given in Table 2-6. The 1997 wellfield pumping annual record is reported as a normal weather year. Conversely, the dry weather pattern in 1998 resulted in peak production requirements to meet demand. Similarly, the unseasonably wet weather experienced in the summer of 1999 resulted in abnormally low production requirements. Notably, unit pumpage from well

Nos. 10, 14, 21, and 25 was considerably less than the other wells in 1997. These wells are low-efficiency units and are typically reserved for peaking supply only.

TABLE 2-6
1997 Annual Groundwater Production

Well No.	Million Gallons	mgd
1	67.9	0.18
2	36.2	0.09
3	61.4	0.17
4	65.4	0.18
5	47.5	0.13
6	65.8	0.18
7	37.5	0.10
8	81.8	0.22
10	12.3	0.03
11	24.8	0.06
12	33.1	0.09
13	36.7	0.1
14	11.0	0.03
15	69.0	0.19
16	46.3	0.13
18	39.6	0.10
19	40.1	0.10
20	56.7	0.16
21	3.1	0.008
23	44.0	0.12
25	4.1	0.01
31	48.0	0.13
32	47.0	0.13
Total	979.3	2.68

Sustainable Yield from the Garber-Wellington Aquifer

As is the case with any water supply, the Garber-Wellington Aquifer is a finite source of freshwater. The aquifer has a low transmissivity and the recharge area is limited. The aquifer contains saline water at the base and this water tends to move upward and replace freshwater in areas of heavy pumpage, resulting in diminishing yield. This assessment of sustainable yield is merely an estimate considering the limited database. The only method of quantifying the sustainable yield to a more accurate degree is to obtain additional field data on the aquifer including hydraulic characteristics, geology, and water quality. Then, a three-dimensional groundwater flow and solute transport model would have to be developed to answer key questions of the yield. Nevertheless, in order to assess the sustainable yield, the aquifer must be divided into two distinct areas, the unconfined area (recharge area) and the confined area. Each area has differing characteristics.

The City of Norman production wells are located in confined parts of the aquifer. As discussed in 2.2.3, the confined part of the aquifer receives about 1.25 to 2.5 mgd of water from the recharge area to the east. This recharge volume has been exceeded in the past, especially in the past few years. Based on these data it is clear that water is being mined from the aquifer. Drawdowns of water levels were as high as 180 feet during the last two summer high-pumpage periods.

When the rate of water withdrawal exceeds the horizontal flow rate from the recharge area two things occur: (1) the potentiometric pressure in the aquifer declines; and (2) the saline water at the base of the aquifer moves up to replace freshwater extracted from the aquifer. The water budget (i.e. inflow less withdrawal) of the inflows and withdrawals will determine how long a given withdrawal rate can be maintained before saline water enters any given production well, which would curtail use.

The western area sustainable yield is already believed to be exceeded by the existing rate of pumping. Water is being mined from the aquifer and eventually the freshwater will be replaced by the deeper saline water. Any incremental increase in current water production from this area will accelerate the mining effect and saline water will become a problem. Some unresolved technical issues include: (1) determining the length of time the existing pumping scenario can be maintained; and (2) determining the effects of increased pumpage. It is not possible to answer these questions with the current database. However, it would be prudent to not further develop the western part of the aquifer without obtaining answers to these questions. Past recommendations on developing only in the unconfined part of the aquifer to the east were correct. The current wellfield in the west can be used to meet peak demands and for episodic use.

The eastern area does show some potential for future water supply development. As water is withdrawn from the unconfined aquifer, the drawdown creates additional potential storage and can enhance recharge. One of the issues to be faced with future water supply development in this area is that of communication with surface water bodies or indirect withdrawals. There is already great dependence on the use of surface water from Lake Thunderbird, and any groundwater withdrawals that decrease stream flows or extract water from the reservoir do not really add to the supply. There are also legal water rights issues with regard to additional well development.

Hydrogeologic studies of the eastern unconfined area are not complete enough to assess the quantity of water that is available, or the impacts that would occur from the withdrawal. Before any additional wells are constructed in the eastern area, we recommend unbiased hydrogeologic studies to obtain answers to the aquifer yield questions. Also, the transmissivity of the aquifer in the eastern area is low, meaning that the supply of water is limited. It is probable that an additional 10-mgd (or more) could be sustained if withdrawals were shifted in part to the eastern area, however, the chance for surface water influence would be increased and consequently the requirement of treatment.

Conclusions on the Groundwater Resources

The sustainable yield of the Garber-Wellington Aquifer is quite limited and no detailed assessment of the aquifer has been made to establish sustainable yields. The current water use from the western, confined part of the aquifer exceeds the sustainable yield in that area and water is being mined from the aquifer. Continued mining of the aquifer in the west will eventually lead to the production of saline water. It is not possible to assess how long the supply will remain viable under such conditions. Further development of the eastern area is possible, but development should be based on additional hydrogeologic data so as not to negatively impact recharge to the confined portion of the aquifer and the existing wellfield.

It is recommended that the City begin to acquire the hydrogeologic data necessary to establish the sustainable yield of the Garber-Wellington Aquifer. This will involve the measurement of water levels in all of the existing product wells, the construction of some monitoring wells with water level recorders, and the establishment of a water use data base. Aquifer performance testing and hydrologic modeling will be necessary components of the investigation in later phases.

The current yield of approximately 4.2 mgd from the existing wellfield can be maintained in the near future. In the absence of a future hydrologic investigation, a sustained yield beyond 4.2 mgd from the existing wellfield is not recommended. If future investigation is limited, a reduction in pumping in the western wellfield may be prudent with capacity replacement to the east in order to sustain the current 4.2-mgd capacity for the 40-year planning horizon. As discussed in Section 3.0, Alternatives Evaluation, it is probable that future hydrogeologic data will show an additional 10 mgd of water supply could be gained in the eastern portion of the aquifer, but development should be based on such data and initiated through a carefully planned program.

2.2.4 Water Resource Planning Capacity

Annual-average water demand projections over the planning horizon were based on the normalized historical trend in population and water use. As determined in Section 1, Baseline Development, and subsequent workshops, the target water supply capacity for the planning horizon is the summation of projected demand and an acceptable reserve capacity to compensate for sensitivity in total population growth, service population, land availability, per capita water use, maximum-day water use, rate structures, weather, and conservation measures. A 20-year window was applied to the projected annual-average demand to establish the targeted water supply capacity (or water resource planning capacity). Figure 2-7 presents the targeted water supply and production capacities for the planning horizon as presented in Section 1.4.4. Also depicted on Figure 2-7, for comparison

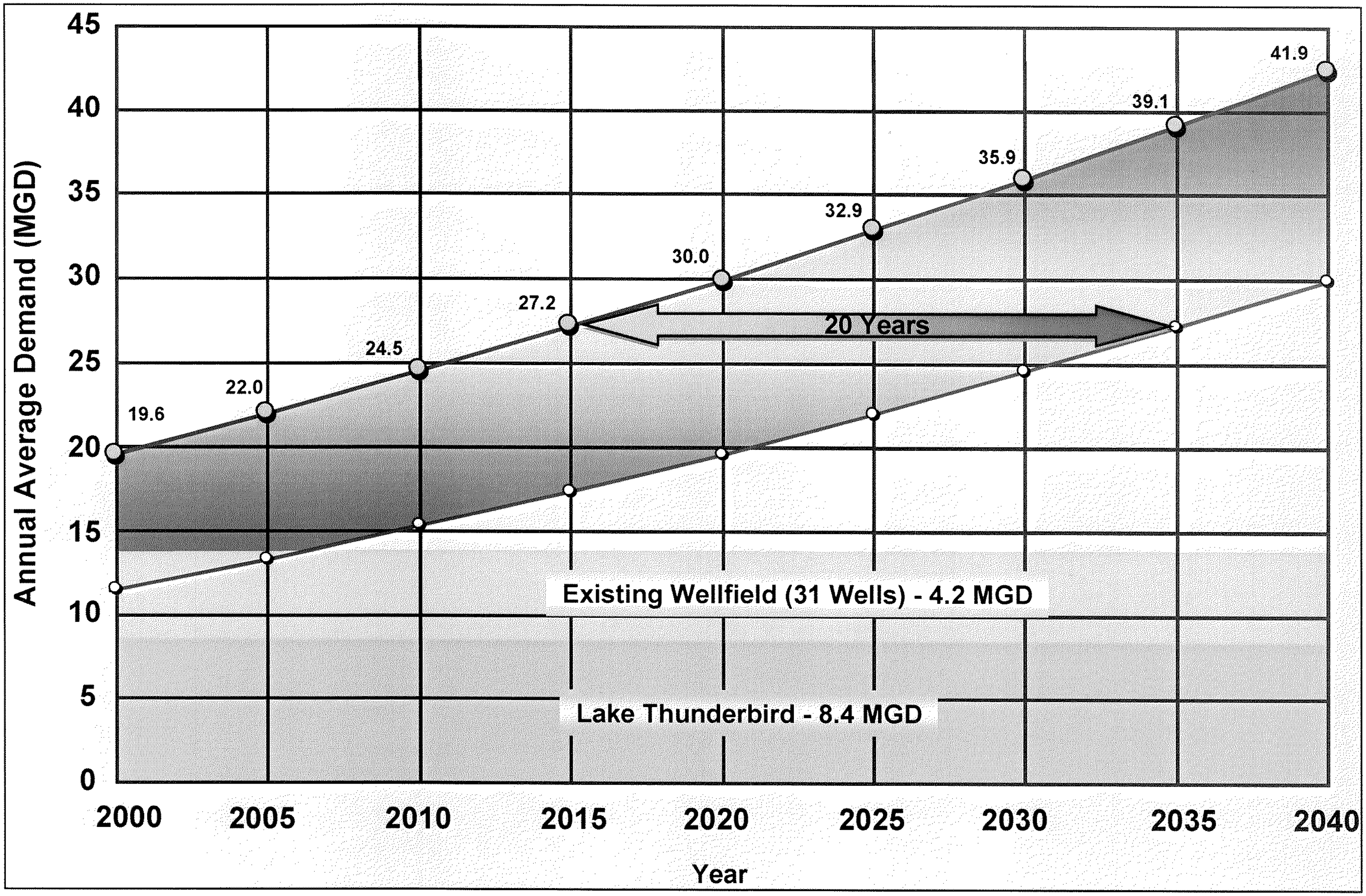


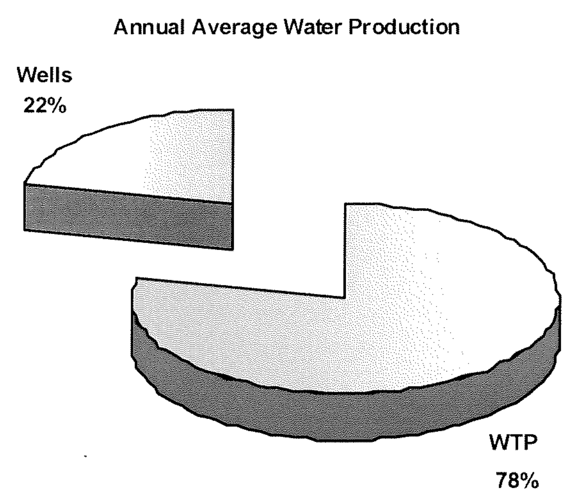
FIGURE 2-7
Existing Supply Capacity and Projected Annual Average Daily Water Demands

to demands, are the safe yields from the City's current water resources. From this analysis, the target water supply (resource) capacity is projected to double from approximately 20 mgd in Year 2000 to 42 mgd in Year 2040.

2.3 Water Treatment and Production

2.3.1 General

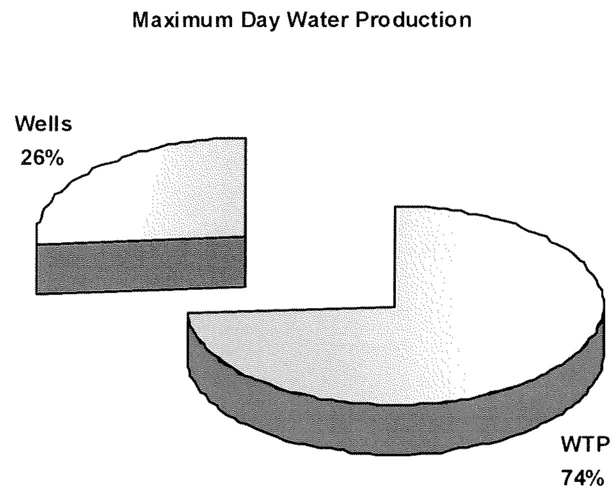
As previously discussed, the City uses both surface water and groundwater for its public water supply. Surface water supply, which is obtained from Lake Thunderbird, is treated at the Norman WTP prior to distribution. The City's wellfield, currently comprised of 31 wells, extracts groundwater from the Garber-Wellington aquifer and pumps directly into the distribution system. With the City utilizing its full COMCD allocation from Lake Thunderbird, approximately 70 percent of the current total water consumption demand on an annual-average basis is supplied by surface water. This practice was adopted to maintain withdrawal from Lake Thunderbird within the City's current surface water supply allocation limit. Until a long-term solution for additional water supply is developed, the demand residual must be supplied from the Garber-Wellington Aquifer. Figure 2-8 illustrates historic (1994 through 1998) average-annual water production from the WTP and groundwater wellfield in meeting average-daily demands.



Annual Average Production			
Year	WTP (MGD)	Wells (MGD)	Total (MGD)
1994	9.2	1.0	10.2
1995	8.9	1.8	10.7
1996	8.0	2.8	10.9
1997	7.8	2.7	10.4
1998	8.7	3.5	12.2
Historic Average	**8.5**	**2.4**	**10.9**

FIGURE 2-8
Historic Annual Average Water Production

Both Lake Thunderbird and the Garber-Wellington Aquifer provide the City with natural storage to provide the volume differential between maximum-day and average-daily demands. To realize the benefits of natural storage provided by these sources, the WTP and the groundwater wellfield are operated as peaking facilities. Water production from both the WTP and groundwater wellfield is increased above annual-average to augment each other in meeting maximum-day demands. Hydrological characteristics of the lake and the aquifer limit the duration this maximum production level can be sustained. Fortunately, water consumption varies over the year. Therefore, the water system, and hence water production requirements, experiences peak demands (above average daily) as well as off-peak (below average daily) demands. Typically, peak water consumption occurs during the summer months, as outdoor water use such as irrigation increases. Water demands decline during the winter months when outside water use is typically at a minimum. Figure 2-9 summarizes the historic peak production from the WTP and groundwater wells in meeting maximum-day demands. Notably, WTP maximum-day production includes storage volume contained in the clearwells. As such, maximum-day production is not considered WTP firm production capacity.



Maximum Day Water Production			
Date	WTP (MGD)	Wells (MGD)	Total (MGD)
June 29, 1994	15.1	5.4	20.5
July 14, 1995	15.0	5.9	20.9
July 8, 1996	14.9	5.4	20.3
July 27, 1997	14.8	5.0	19.8
August 18, 1998	15.9	5.1	21.0
Historic Average	**15.1**	**5.4**	**20.5**

FIGURE 2-9
Historic Maximum Day Water Production

As stated, Lake Thunderbird and the Garber-Wellington Aquifer operate in conjunction to meet the City's demands. Figure 2-10 depicts the trends in production for 1999 and shows the relationship between average-annual demand and the maximum-day demand for this year.

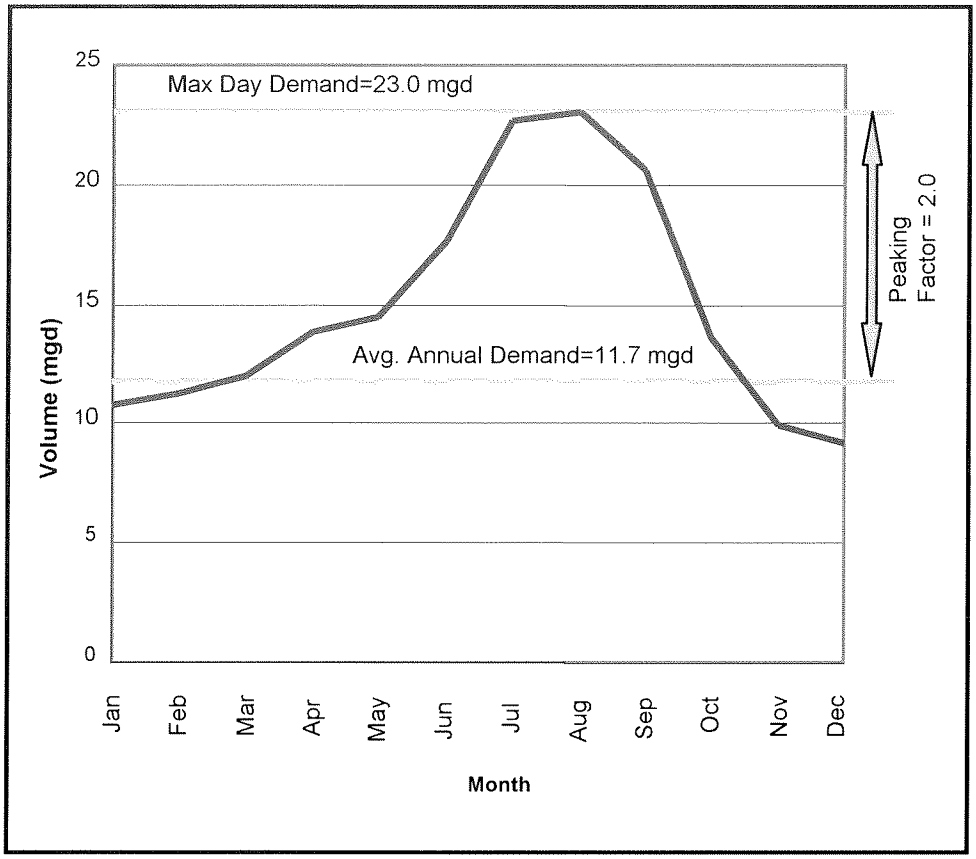


FIGURE 2-10
Total Water Production, 1999

The following sections present an evaluation of the City's water treatment and production facilities. Section 2.3.2 discusses the evaluation of the WTP, including historic and current production, treatment process train, rated treatment capacity, condition of the facilities, and support facilities. Section 2.3.3 discusses the evaluation of the City's groundwater wellfield, including historic and current production, well capacity, and condition of the well facilities.

2.3.2 Water Treatment Plant

Water Treatment Plant Operation Summary

Over any year, the WTP annual-average production rate is equivalent to the total volume of water produced for the year divided by 365 days. Water produced from the City's wellfield augments water supplied from the WTP to meet the total average-daily water demands. Based on WTP Daily Operating Logs from 1990 through 1998, the City's WTP has produced, on average, approximately 3 billion gallons of treated water per year. This total annual production is equivalent to a WTP historical annual-average production rate of approximately 8.5 mgd.

In addition to meeting average-daily demands, the WTP along with the groundwater wellfield are operated as peaking facilities to supply maximum-day demands (maximum water consumption demand over a 24-hour period). Considering the maximum-day production for 1990 through 1998, the City's WTP production rate, on average, has increased to 15.0 mgd to meet maximum-day demands. Figure 2-11 depicts the WTP annual-average and maximum-day production rates for the years 1990 through 1998. With available clearwell volume, the WTP has the capacity to produce maximum-day production rates in excess of the Lake Thunderbird raw water conveyance pipeline.

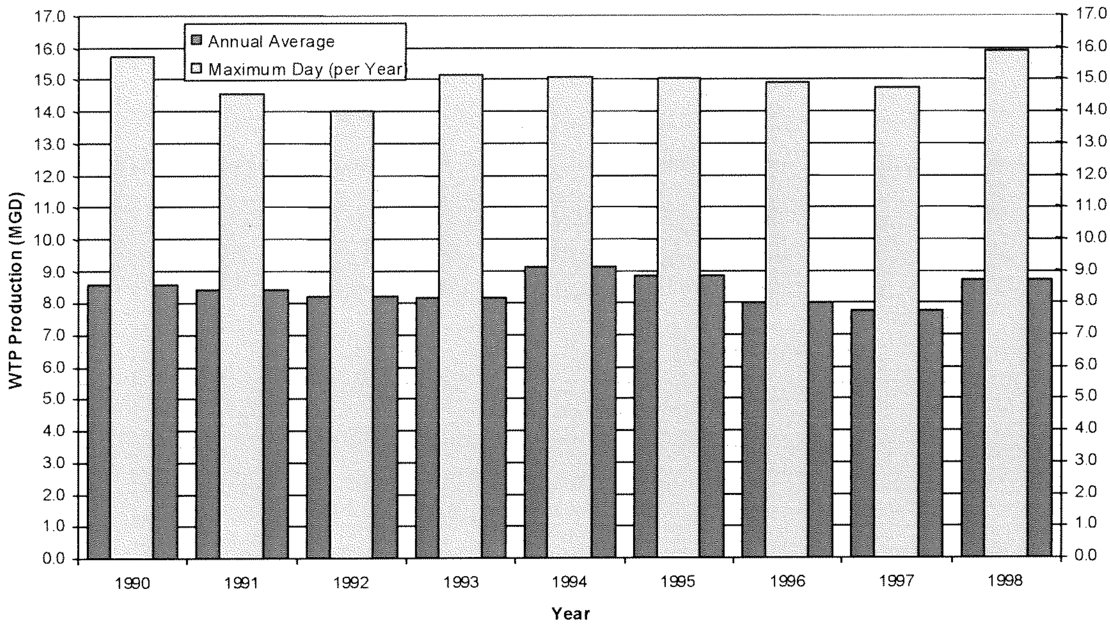


FIGURE 2-11
Historic WTP Annual Average and Maximum Day Production Rates

As previously indicated, water production from the WTP will vary over any given year to meet varying water consumption demands. Based on the City's WTP and Groundwater Well Daily Operating Logs, the City's water system typically experiences peak-water demands during the months of May through September, with the months of July or August typically having the greatest water consumption. To meet peak-monthly demands, the City's WTP production rate during these months can increase significantly over the average-annual production rates. Based on 1990 through 1998 production logs, the WTP has produced approximately 10.6 mgd of treated water, on average, over these five months (May through September). Additionally, the average WTP production rate for the months of July and August, respectively, for these years is approximately 12.3 mgd and 11.4 mgd.

A sample window depicting monthly average WTP production rates is provided on Figure 2-12. Figure 2-12 depicts the annual-average, monthly-average, and maximum-day (per month) WTP production rates for 1997. The data for 1998 is not shown in this instance as it illustrates historic drought and does not accurately represent historic demands.

For 1999, the WTP produced more than three billion gallons of treated water. Total production is equivalent to a current WTP annual-average production rate greater than 9.0 mgd. Additionally, for the months of July and August, respectively, the WTP monthly-average production rate was 12.6 mgd and 14.1 mgd. Figure 2-13 summarizes the current WTP production rates.

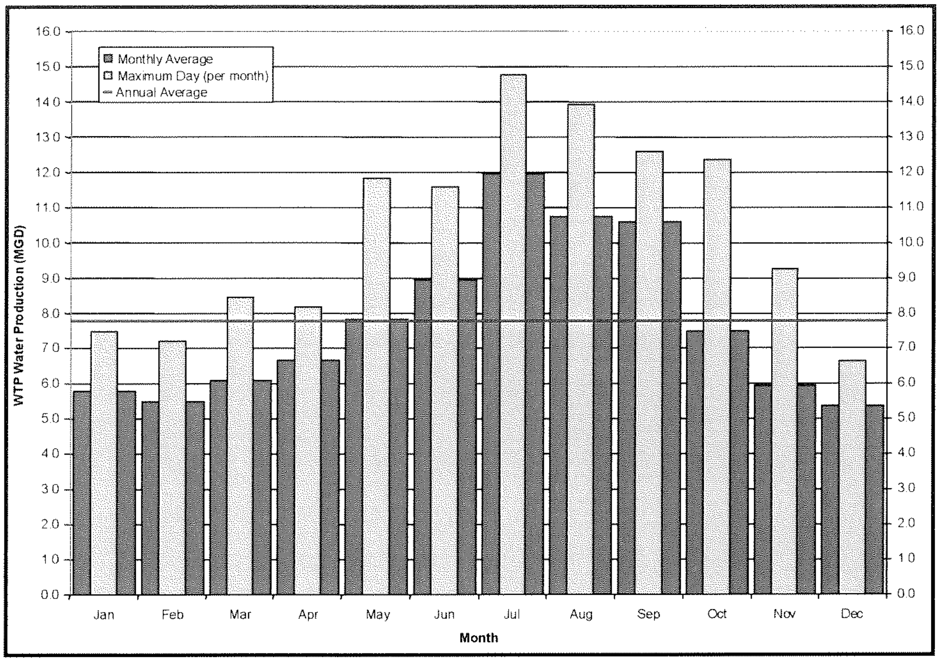


FIGURE 2-12
Historic WTP Monthly Production Rates
1997 Sample Window

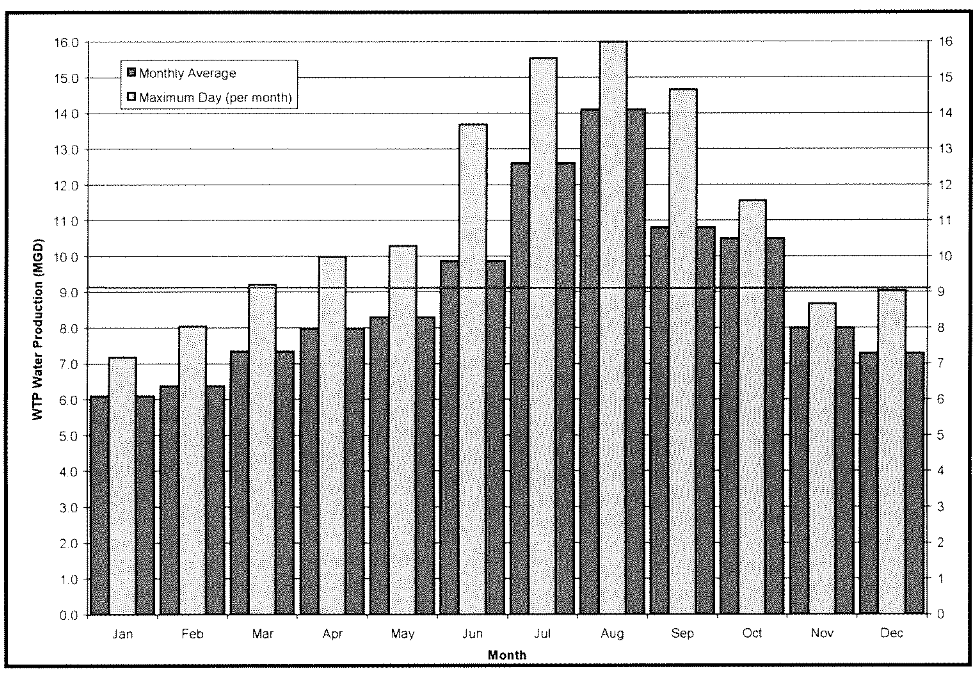


FIGURE 2-13
Current WTP Production
January through October 1999

Although 1999 is considered a typical weather year, a comparison of Figures 2-12 and 2-13 shows that the WTP produced more treated water for each month in 1999 as compared to 1997. As reported in Section 1, Baseline Development, overall water consumption demand has increased for the City. To meet this increasing demand, the WTP produced approximately 16.7 percent more treated water in 1999 than in 1997 (based on production data for the reported months). Table 2-7 summarizes the comparison between WTP monthly production for these two years.

TABLE 2-7
1997 Versus 1999 WTP Monthly Production [a]

Month	WTP Production (mgd) 1997	WTP Production (mgd) 1999	Percent Increase
Jan	5.8	6.1	5.2%
Feb	5.5	6.4	16.4%
Mar	6.1	7.3	19.7%
Apr	6.7	8.0	19.4%
May	7.8	8.3	6.4%
Jun	9.0	9.9	10.0%
Jul	12.0	12.6	5.0%
Aug	10.7	14.1	31.8%
Sep	10.6	10.8	1.9%
Oct	7.5	10.5	40.0%
Nov	5.9	8.0	35.5%
Dec	5.4	7.3	35.2%
Average	7.8	9.1	16.7%

Note:
[a] Data adopted from WTP Daily Operation Logs.

Water Treatment Plant Process Train

The Norman WTP, with an original design capacity of 6.0 mgd, was put into service in 1966. In 1983, the original WTP was expanded to a rated capacity of 14 mgd. Current process units at the WTP include three upflow clarifiers, two recarbonation basins, eight mixed media filters, and two clearwells. Additionally, associated facilities at the WTP include an operations/laboratory building, three flow-control vaults, chemical feed facilities located in a chemical building, six sludge ponds, an elevated filter backwash tank, and two high-service pump stations (each with four pumping units). A schematic of the current treatment process train showing the interrelationship of the process units and chemical feed units is shown on Figure 2-14. Each process unit and chemical feed unit is briefly discussed in the following paragraphs.

Raw water from Lake Thunderbird is conveyed to the COMCD raw water storage tank, located at the head of the plant. From the tank, water is routed through the COMCD

metering vault to a chemical feed vault. At the chemical feed vault, chlorine followed by ammonia is added to the raw water to form a chloramine disinfectant residual. The chloramine disinfectant residual is maintained through the process treatment train as well as in the distribution system (to prevent regrowth of pathogenic organisms). Because a chloramine residual is maintained through the treatment train, contact time for primary disinfection is achieved with the clarifiers, recarbonation basins, filters, clearwells, and interconnecting piping. In addition to chlorine and ammonia, potassium permanganate is added to the water to aid in taste and odor control.

From the chemical vault, flow is routed to the three upflow clarifiers through the three associated flow-control vaults. At the flow-control vaults, alum is added to the process water. Alum is a coagulant, which serves to adsorb and electrically destabilize colloidal particles suspended in the process water. The destabilized colloidal particles can then be formed into settable size floc and removed from the process water in the upflow clarifiers. Flow to the clarifiers enters at the flocculation chamber located in the center of the clarifiers. Lime, polymer, and powder activated carbon (PAC) are added to the process water at the flocculation chamber. The addition of lime raises the pH of the water so the carbonate form of calcium and magnesium will precipitate out of the water, thereby, softening the water (removing hardness). Polymer is added as a coagulant to help form settable size colloidal and carbonate floc. PAC is added to adsorb, or remove, taste and odor causing compounds.

Within the clarifier's flocculation chambers, the chemicals and process water are gently mixed to promote the formation of settable size floc. Process water from the flocculation chambers flows to the outer settling chamber of the clarifiers. Clarification takes place as the process water flow velocity is lowered, thereby, allowing the floc to settle out of suspension. Additionally, the clarifiers are designed so that, under proper operation, a blanket of suspended floc is maintained in the settling chamber. Particles in the process water are trapped as the water flows through this sludge blanket. The depth and density of the sludge blanket is controlled through sludge wasting. Sludge wasting refers to removing the sludge that has accumulated in the clarifiers and transferring it to the sludge lagoons.

Following clarification, the process water is stabilized in the two recarbonation basins, which operate in parallel. Carbon dioxide is added to the process water to lower the pH, which sequesters the lime softening process and reduces the potential for scale buildup in downstream pipes, filter media, and clearwells. Fluoride (sodium silicofluoride) is added to the process water during recarbonation to aid in consumer dental health. Polymer is also added to the process water as a filter aid.

Filtration at the WTP includes mixed-media and dual-media filter beds to remove particulate matter unable to settle out of suspension in the clarifiers. The process water passes through the filter beds where a majority of the particulate matter is removed in the top portion, as well as the entire depth of the bed. The WTP has four mixed-media filters constructed of a garnet sand and anthracite media bed with gravel support and Leopold

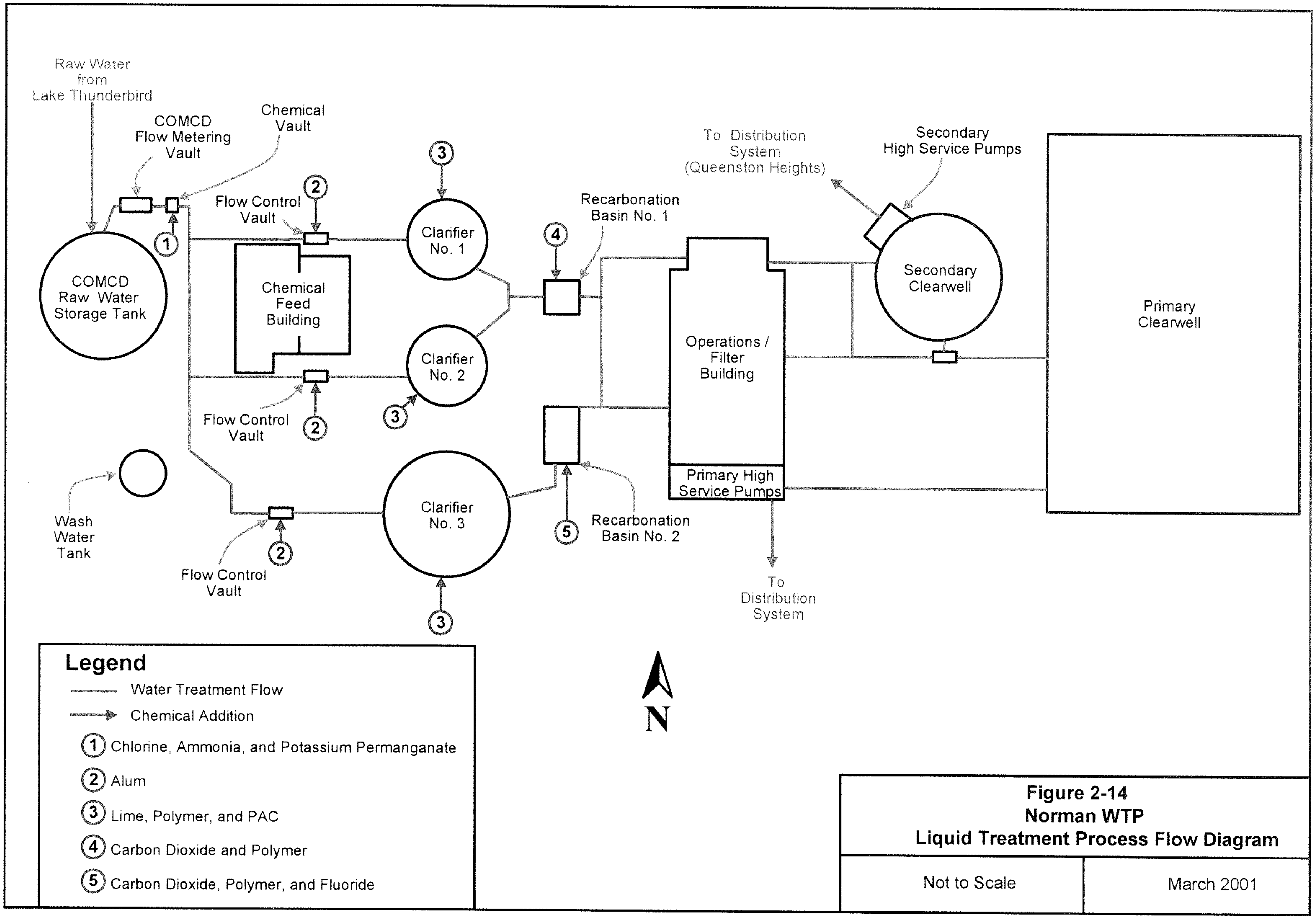


Figure 2-14
Norman WTP
Liquid Treatment Process Flow Diagram

Not to Scale

March 2001

clay-tile underdrains. The four older filters consist of sand-filtration media with gravel-support media and Wheeler underdrains.

Following filtration, water is routed to the two underground clearwells. The primary clearwell is a rectangular tank that provides approximately 6 MG of finished water storage. Whereas, the secondary clearwell is a circular tank that provides approximately one MG of finished water storage. The purpose of the clearwells is threefold: (1) provide sufficient contact time for disinfection; (2) provide supplemental in-system volume to meet peak demands; and (3) provide WTP operational volume for chemical feed make-up, filter backwash, plant washdown, and plant potable supply.

Water Treatment Plant Capacity

Treatment Process Units. As previously mentioned, the WTP with expansion in 1983 was designed for a capacity of 14 mgd. Pursuant to EPA SDWA guidelines, ODEQ publishes construction standards for WTP process units. Table 2-8 summarizes these criteria in comparison to the City's WTP at the design capacity of 14 mgd. Additionally, Table 2-8 provides an equivalent maximum-rated plant capacity based on the ODEQ design standards. As shown, the WTP at the design flow rate of 14 mgd is well within the ODEQ suggested construction standards.

TABLE 2-8
WTP Process Units Design Criteria and Capacity

Norman WTP Treatment Component/Description	Evaluation Criteria	WTP Criteria at 14 mgd	ODEQ Design Criteria	WTP Equivalent Maximum Capacity
Upflow Clarifiers/Softeners				
Clarifiers Nos. 1 & 2 - 52' diameter by 12.5' SWD clarifiers with 1,947 ft^2 clarification area, each.	Weir Loading (gpd/ft)	22,300	≤ 28,800	26.5 mgd
Clarifier No. 3 – 96' by 14' SWD clarifier with 6,636 ft^2 clarification area.	Upflow Rate (gpm/ft^2)	0.92	≤ 1.75	18.1 mgd
Filtration				
Four 536.5 ft^2 dual media filters Four 464 ft^2 mixed media filters	Filtration Rate (gpm/ft^2) [a]			
	Nominal	2.8	3	15 mgd
	If demonstrated		4	20 mgd

Note:
[a] Filtration rate is based on one filter offline for backwashing. For this analysis, filtration rate considers one of the larger (536.5 ft^2) filters offline.

City staff indicated the largest clarifier can consistently treat 11 mgd; whereas, the two smaller clarifiers can consistently treat 3 to 3.5 mgd each. Staff also indicated the chemical feed facilities have sufficient capacity to support a plant flow rate of 17 mgd. Additionally, the mixed-media filters can produce high-quality filtered water at this high flow rate. Based on the ODEQ design standards presented in Table 2-8, the WTP could be rated at 17 mgd.

Disinfection Practice. The SWTR requires that treatment must achieve at least 99.9 percent (3-log) removal and/or inactivation of *Giardia lamblia* and 99.99 percent (4-log) removal and/or inactivation of viruses. Additionally, the Enhanced SWTR requires 99 percent (2-log) removal and/or inactivation of *Cryptosporidium*.

EPA allows credit for 2.5-log removal of *Giardia* cysts and 2-log removal of viruses and *Cryptosporidium* for well-designed and operated water treatment plants using conventional treatment (i.e., coagulation, flocculation, sedimentation, and filtration) and that meet turbidity requirements under the rules. Hence, for conventional plants such as the Norman WTP, the primary disinfection process must achieve the difference of at least 0.5-log inactivation of *Giardia* cysts and 2-log inactivation of viruses.

To quantify the effectiveness of a plant's primary disinfection process and, therefore, the plant's ability to provide the required inactivation of microbes, EPA developed the CT concept. With this method, inactivation credit is determined by multiplying the disinfectant residual concentration (C), in mg/L, by the disinfectant contact time (T), in minutes. The contact time used in the calculation is the time it takes 10 percent of the water to move from the disinfectant application point to the point where the disinfectant residual concentration is measured. The contact time may be determined empirically by tracer studies or theoretically by rule-of-thumb baffling factors included in the EPA's *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources*. For compliance, the inactivation credit (calculated CT) must be greater than the CT value required by the SWTR. The required CT values are dependent upon the organism in question (*Giardia lamblia, Cryptosporidium*, or viruses) and on the water's pH and temperature, which affect the activity of certain disinfectants.

The City's disinfection study (*Norman Water Treatment Plant Disinfection Study, 1993*) indicates the WTP can comply with current EPA disinfection contact time requirements at a flow rate of 17 mgd. However, chloramine residual must be maintained through the clarifiers, recarbonation basins, mixed-media filters, clearwells, and inter-connecting piping to meet required disinfection contact times. Also, high-service pumping from the secondary (smaller) clearwell is limited to fully comply with disinfection requirements. The secondary clearwell serves the Queenston Heights, Sonoma Park, Royal Oaks, and Summit Lakes areas (high service area). The primary (larger) clearwell serves the remainder of the distribution system (low service area).

Table 2-9 summarizes the WTP disinfection practice at a plant flow rate of 17 mgd. The analysis presented in Table 2-9 assumes the same conditions as presented in the City's disinfection study, except for chloramine residual through the treatment train. Based on the 1993 through 1998 WTP Daily Operating Logs, the chloramine residual through the WTP has increased from 2.2 mg/L (as reported in the disinfection study) to 2.5 mg/L (on average).

To fully realize the WTP capacity of 17 mgd, some modification to the existing WTP may be warranted. Based on the City's disinfection study, it is recommended the City consider adding baffles to the secondary clearwell to ensure disinfection contact time is achieved under varying operation and water-demand scenarios. Secondary clearwell baffling would also provide greater operation latitude with respect to high-service pumping. Additionally, greater control of microbes, disinfectants, and disinfection byproducts are major focuses of anticipated future water quality regulations. It is anticipated that future regulations will become more stringent in limiting finished water disinfectant levels and associated disinfection byproducts while simultaneously requiring greater microbial removal/ inactivation. Depending on the finalized provisions of these future regulations, the WTP current disinfection practice may require modification to continue to meet disinfection requirements over the planning horizon. Potential modifications could range from baffling the secondary clearwell or providing additional clearwell volume, to conversion, to a more powerful oxidant/disinfectant such as ozone. Anticipated future water quality regulations and City compliance status are discussed in greater detail in Section 2.4.

TABLE 2-9
WTP Disinfection Practice Criteria

Parameter [a]	Condition
Raw Water Flow Rate	17.0 mgd
Primary High Service Pumping Rate	14.7 mgd
Secondary High Service Pumping Rate	3.2 mgd
Clearwell Depth	11 feet
Temperature	20°C
pH	9.0
Critical Detention Time [b]	139 minutes
Combined Chlorine Residual [c]	2.5 mg/L
Contact Time	**348 mg/L-min**
Required CT [d] (for 2-log virus inactivation using chloramines)	**321 mg/L-min**

Note:
[a] Parameters adopted from the Summer Condition as reported in the Norman WTP Disinfection Study.
[b] Critical detention time is based on the flow path through the treatment train and secondary clearwell.
[c] Average combined chlorine residual based on 1993 through 1998 WTP Daily Operations Log.
[d] Required CT is based on the reported parameters and criteria adopted from the EPA's Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Source. For chloramine disinfection, 2-log virus inactivation requires greater CT than for 0.5-log inactivation of Giardia, and therefore is the controlling criteria.

Chemical Feed Facilities. Chemicals used for water treatment at the WTP include alum, lime, PAC, carbon dioxide, potassium permanganate, fluoride, chlorine, and ammonia. The interrelationship of these chemicals and process units has been discussed previously. Based on the recent 12 months of WTP operation (November 1998 through October 1999), monthly chemical use at the WTP is presented in Table 2-10. Also shown is the average-annual dose and maximum- and minimum-monthly doses for each chemical. As previously mentioned,

Table 2-10
WTP Chemical Use

Date	Treated Water (MG)	Alum (lb)	Lime (lb)	Fluoride (lb)	PAC (lb)	Potassium Permanganate (lb)	Polymer (lb)	Ammonia (lb)	Carbon Dioxide (lb)	Chlorine (lb)
Nov-98	198	56,590	162,766	3,009	12,421	792	1,171	1,336	8,795	5,817
Dec-98	190	49,232	162,843	2,933	6,750	762	1,135	1,227	11,016	5,297
Jan-99	189	50,843	181,349	2,805	4,417	627	1,046	1,206	14,756	5,485
Feb-99	179	53,308	131,949	2,753	2,769	539	1,068	1,025	12,946	5,065
Mar-99	228	66,631	162,651	3,480	3,010	685	1,631	1,300	9,938	5,894
Apr-99	240	66,672	165,945	3,750	3,035	710	1,629	1,339	8,692	6,153
May-99	257	78,676	185,460	3,953	3,184	771	1,354	1,402	7,696	6,844
Jun-99	296	82,360	216,893	4,465	3,524	889	2,022	1,529	7,152	8,628
Jul-99	391	101,034	275,080	5,961	3,229	1,175	3,089	2,023	5,477	12,338
Aug-99	437	115,146	294,721	6,593	8,128	1,312	3,135	2,612	4,581	17,550
Sep-99	324	85,837	217,018	4,991	9,707	875	1,945	2,102	6,671	11,574
Oct-99	252	66,305	167,629	3,423	6,508	755	1,501	1,599	5,841	8,324
Total	**3,181**	**872,634**	**2,324,304**	**48,116**	**66,682**	**9,892**	**20,726**	**18,700**	**103,561**	**98,969**
Minimum Month Dose (mg/L)		31.0	79.8	1.6	1.0	0.3	0.6	0.6	1.3	3.1
Average Annual Dose (mg/L)		32.9	87.6	1.8	2.5	0.4	0.8	0.7	3.9	3.7
Maximum Month Dose (mg/L)		36.7	115.0	1.9	7.5	0.5	0.9	0.8	9.4	4.8

City staff indicated that chemical feed facilities have sufficient capacity to support a WTP flow rate of 17 mgd.

Water Treatment Plant Condition

The WTP is a very well-maintained and operated facility. The City has experienced peak water demands over the last two years. However, the WTP was able to operate at peak production levels to meet these demands without a single incident of downtime. This accomplishment is a testament to the City staff's dedication to preventive maintenance and overall operation of the WTP. Additionally, based on site visits to the WTP, facilities and equipment are clean, painting needs appear to be up-to-date, and WTP grounds are well kept.

Based on site walk-through and discussion with City staff, structures, mechanical equipment, and chemical feed facilities appear to be in good condition. However, there have been maintenance problems with the original pneumatic controls associated with the original WTP. These pneumatic controls are approaching the end of their service life and parts are difficult to obtain. There are also signs of corrosion on the original WTP steel piping, which is also approaching the end of its useful service life.

Support Facilities

Raw Water Conveyance. The COMCD owns and operates Lake Thunderbird's raw water conveyance system. The raw water conveyance system serving the City includes a pump station with four, 200-horsepower (hp) vertical turbine pumps, an elevated surge tank, and approximately 28,500 feet of 33-inch and approximately 12,700 feet of 30-inch concrete piping. The raw water conveyance system transfers water from Lake Thunderbird to the COMCD-owned one-MG storage tank located at the head of the WTP.

The raw water conveyance system has a rated capacity of 14 mgd. The raw water system can, at times, deliver between 15 to 16 mgd. However, the design operating pressure of the concrete pipe is exceeded at flows greater than 15.5 mgd. Additionally, the conveyance system cannot support these high flow rates reliably. For example, typically at flows greater than 14 mgd (and sometimes less), the pumps overflow the elevated surge tank. Furthermore, City staff indicates that flow cannot be increased above 14 mgd on demand, especially after periods of low flows. However, staff also reports that after continuous operation at peak, conveyance flows can increase upwards of 15 to 16 mgd with time.

These phenomenon are likely due to transient air entrapment in the pipeline, but could also be attributable to solids accumulation in the piping, or both. Figure 2-15 provides a sample window depicting raw water conveyance to the WTP as compared to total water consumption demand for August 1999. As shown, raw water conveyance, and hence WTP production is limited to approximately 14 mgd, although a peak conveyance of 16 mgd was achieved on one day. Groundwater production increases to augment WTP production in meeting total water consumption demand.

The expected service life of concrete pipe is 30 to 50 years. The Lake Thunderbird raw water conveyance pipeline was constructed in 1963. As such, the pipeline has exceeded 30 years of service. With this considered, the piping and pipe connection joints conditions are questionable. City staff is planning a study of the raw water conveyance pipeline to determine pipe condition and to evaluate the limited conveyance capacity of the pipeline.

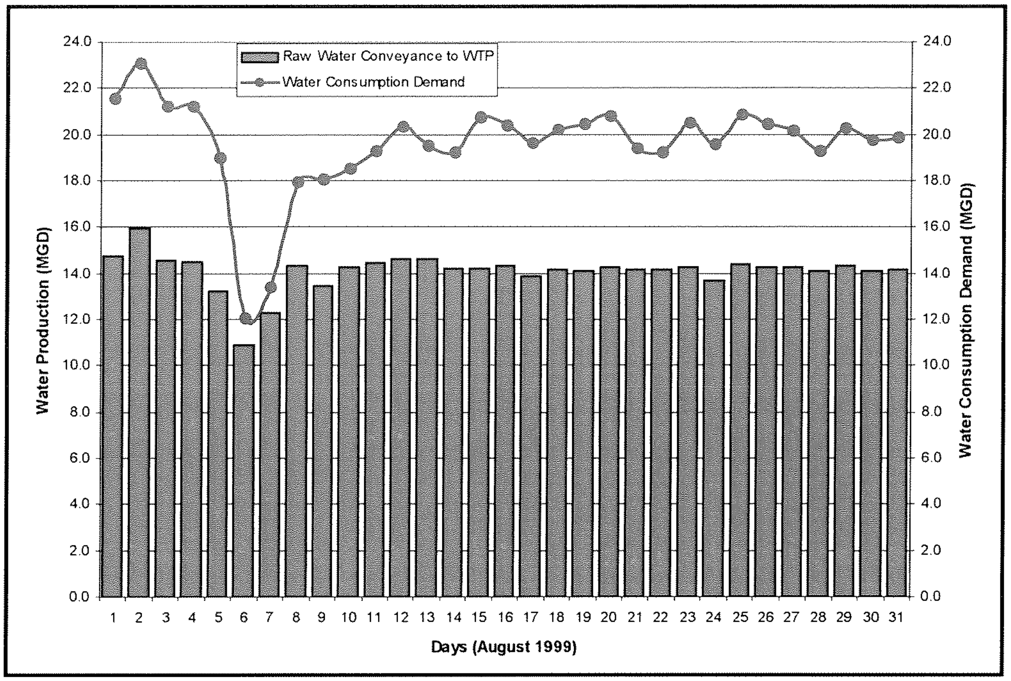


FIGURE 2-15
Raw Water Conveyance to the WTP
August 1999 Sample Window

Sludge Handling and Disposal. Based on hardness removal and alum, polymer, and PAC usage, Table 2-11 provides the calculated sludge production from the treatment process for 12 months of WTP operations (November 1998 through October 1999).

TABLE 2-11
Calculated Sludge Production

Date	Sludge Production (dry tons)
Nov-98	178
Dec-98	161
Jan-99	156
Feb-99	128
Mar-99	175
Apr-99	192
May-99	220
Jun-99	234
Jul-99	281

TABLE 2-11
Calculated Sludge Production

Date	Sludge Production (dry tons)
Aug-99	337
Sep-99	281
Oct-99	180
Total	**2,522**
Monthly Average (ton)	210
Daily Average (ton)	7

The WTP includes six sludge dewatering lagoons. Lagoons temporarily store both sludge from the upflow clarifiers and wash water from backwashing the mixed-media filters. Each lagoon is approximately 40,000-square-feet and provides approximately 2.5 feet of sludge storage. The lagoons are cycled in- and out-of-service depending on sludge production, weather conditions for drying, and lagoon cleaning. Typically, one lagoon is in service at a time. During the drying cycle, decant from the lagoons is recycled to the head of the plant, prior to the three upflow clarifiers. Following dewatering, the City cleans, or removes the solids from the lagoons. Approximately three to four lagoons are cleaned per year. The removed sludge is hauled offsite for disposal at two former sewage lagoons. The two disposal lagoons are approaching capacity and therefore, the City is faced with identifying alternative sludge disposal options.

The six sludge dewatering lagoons at the WTP do not provide sufficient capacity for current water treatment practices at the WTP. The lagoons have been plagued with infiltration of groundwater, which decreases sludge storage capacity and hinders sludge dewatering. Additionally, based on comparison to ODEQ design standards for lime sludge lagoons, the lagoons do not provide sufficient volume for sludge dewatering. Table 2-12 compares ODEQ sludge lagoon criteria versus the existing lagoons at the WTP.

As shown, the existing lagoons at the WTP are approximately 64 percent (based on volume) under capacity, based on ODEQ design criteria and current WTP operation. This deficiency is compounded by groundwater in the bottom of the lagoons. Sludge production is related to WTP treatment capacity. As such, this deficiency would be magnified if the WTP average-annual production rate is increased.

TABLE 2-12
WTP Sludge Dewatering Lagoons

Norman WTP Existing Sludge Lagoons [a]	ODEQ Design Criteria	ODEQ Equivalent Lagoons [b]
5.5 acres (240,000 ft^2) with 2.5 ft usable depth	0.7 acres per mgd of treated water per 100 mg/L hardness removed, based on an usable lagoon depth of 5 feet.	3.6 acres (156,800 ft^2) with 5 ft usable depth
	10 times average filter backwash volume over 24 hour period.	197,800 ft^3
600,000 ft^3	_	981,800 ft^3

Note:
[a] Six lagoons, each approximately 40,000 ft^2 with a usable storage depth of 2.5 ft
[b] Based on November 1998 through October 1999 WTP operation data, average flow rate and average hardness removal is 8.9 mgd and 57 mg/L (as $CaCO_3$), respectfully. Average daily filter backwash volume is 19,780 ft^3 (148,000 gallons) based on January 1997 through June 1998 WTP operation data.

2.3.3 Groundwater Wellheads

Historic Groundwater Wells Operations Summary

Groundwater wells were the only source of supply for the City of Norman prior to the construction of Lake Thunderbird in 1965. The Lake was developed as a surface supply source for the City to meet increased demands due to a growing population. Since the late 1960s, the groundwater wells have produced water, in conjunction with the WTP, to meet the annual-average and maximum-day average demands.

The Daily Operating logs have shown a general increasing trend in well production over the last decade. The maximum-day demand has also risen in conjunction with the rising average-annual demand. Figure 2-16 illustrates the rise in these demands for the Years 1990 through 1998. Although the water production varies from year to year, an increasing trend is shown among the average-annual and maximum-day production rates. The average-annual rate has risen to nearly 3.5 mgd, while the maximum-day production rate rose to over 6 mgd in 1995 and 1997.

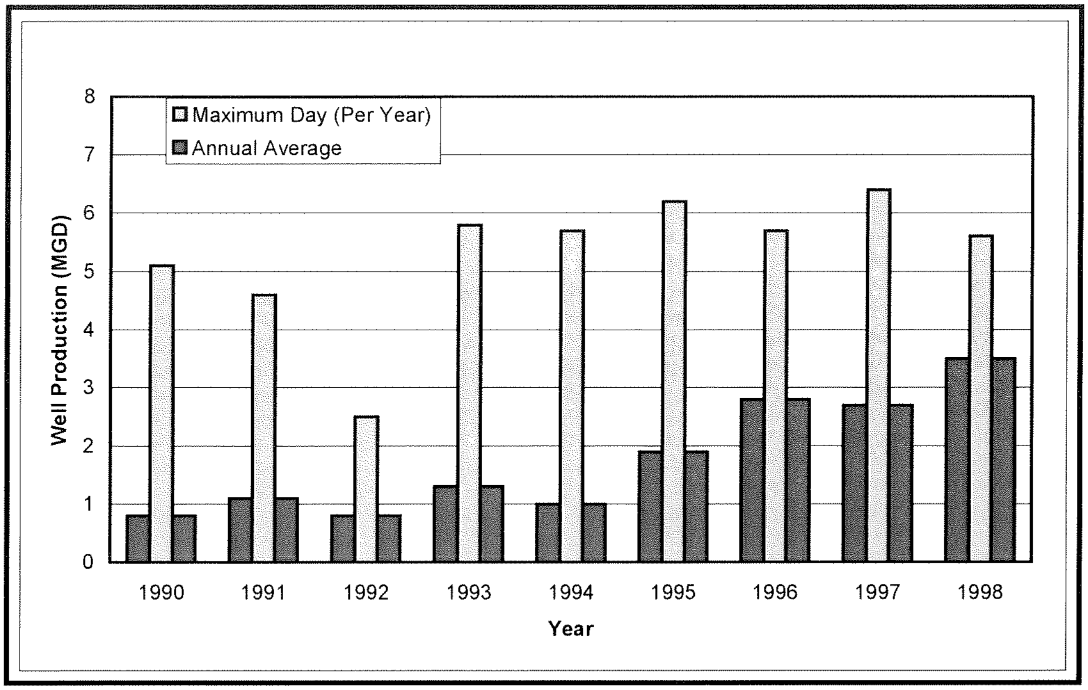


FIGURE 2-16
Historic Well Annual Average and Maximum Day Production Rates

Based on information provided in the Groundwater Well Daily Operating Logs, the peak water demands are experienced during the months of May through September with the months of July and August showing the most water consumption. The production rates of the groundwater wells can increase drastically to meet the demands during these peak months. The production rates for these months rose sharply above the average-annual production rates. Based on the production logs from 1990 through 1998 for these five peak months, the wells have produced an average of 1.9 mgd. Additionally, the production has risen to nearly 2.4 mgd during July and August, the months of maximum demands. These rates are high in comparison to the average-annual demand of 1.77 mgd for the same time period. When considering maximum-day demands, these volumes increase significantly. Additionally, the average production rates for these months and for the years 1990 through 1998 are significantly lower than the production rates for the last few years. This can be attributed to increased demand over the last few years, as well as an increase in the number of wells in the system due to capital improvements projects. Additional wells have allowed the City to increase the total rates of production. Figure 2-17 depicts the monthly-average and maximum-day (per month) production rates for 1997.

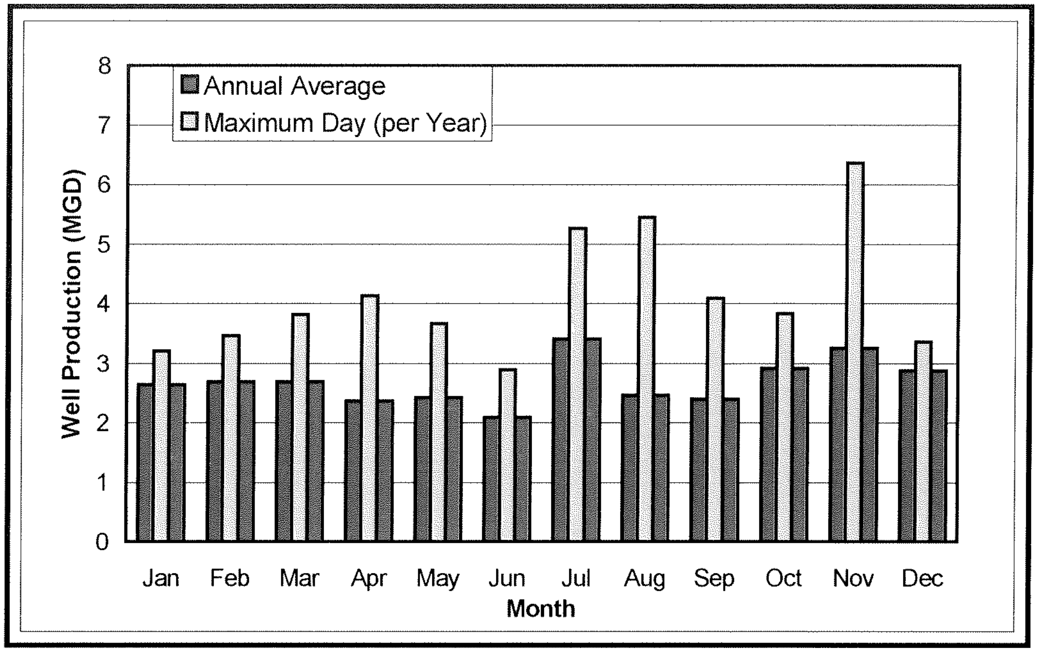


FIGURE 2-17
Historic Well Production Rates for 1997

The production of water from the groundwater wells has risen significantly during the 1990s. An increasing population with ever-increasing demands has forced the City to increase production of water from its WTP and from its wellfield. Additional wells have been drilled to increase production to meet system demands. Figure 2-18 depicts the well production for the months of 1999. Several of the production rates (monthly annual-average demand and maximum-day demand (per month) for 1999 have increased significantly when compared to those for 1997, as shown in Table 2-13.

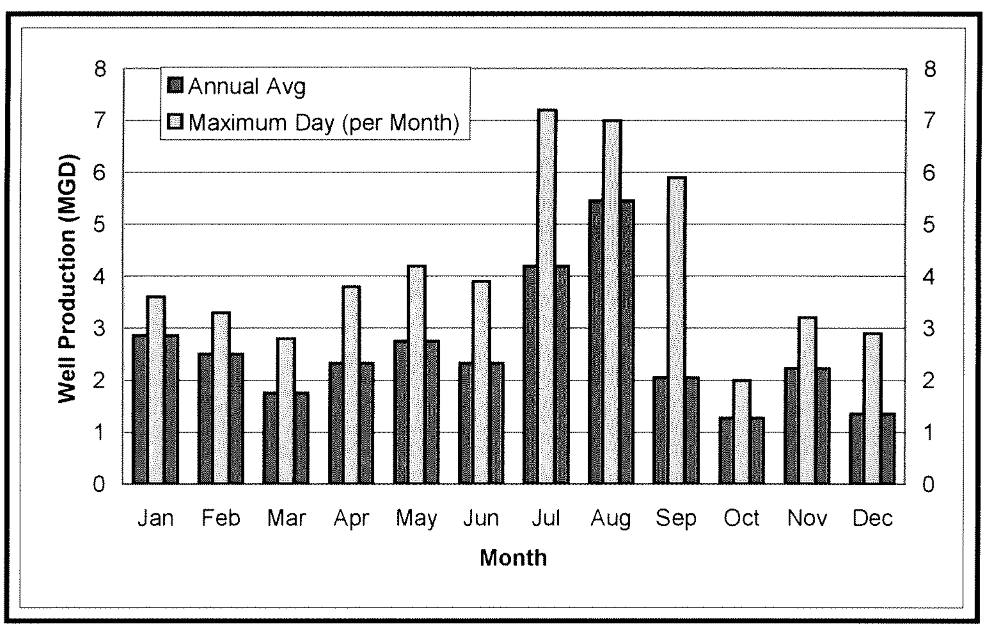


FIGURE 2-18
Well Production Rates for 1999

TABLE 2-13
Percent Change in Production, 1997 Versus 1999

Month	Monthly Average 1997	Monthly Average 1999	Percent Change	Maximum Day 1997	Maximum Day 1999	Percent Change
Jan	2.6	2.9	8.3	3.2	3.6	12.5
Feb	2.7	2.5	-7.1	3.5	3.3	-4.6
Mar	2.7	1.8	-35.9	3.8	2.8	-26.7
Apr	2.4	2.3	-1.7	4.1	3.8	-8.0
May	2.4	2.8	13.6	3.7	4.2	14.4
Jun	2.1	2.3	11.5	2.9	3.9	35.0
Jul	3.4	4.2	23.2	5.3	**7.2**	36.9
Aug	2.5	**5.5**	121.5	5.5	7.0	28.4
Sep	2.4	2.1	-14.6	4.1	5.9	44.3
Oct	2.9	1.3	-56.5	3.8	2.0	-47.8
Nov	3.3	2.2	-33.3	6.4	3.2	-50.0
Dec	2.9	1.4	-51.7	3.4	2.9	-14.7
Annual Average	***2.7***	***2.6***	***-3.7***	***4.1***	***4.2***	***2.4***

In general, sharp increases have occurred during the summer months when demand and consumption rises. One reason for the increased production is the construction of new wells from 1997 through 1999. Some months show a volume decrease over the time period, probably due to a larger volume supplied by the plant to the system instead of the wellfield, or maintenance on the wells. The system may have been operated to decrease well production at times. However, the historic high maximum-month (5.5 mgd) and maximum-day (7.2 mgd) groundwater production occurred in 1999. The monthly-average production has risen by 62 percent from 3.4 mgd to 5.5 mgd. The maximum-day production has risen by 31 percent from 5.5 mgd to 7.2 mgd. These increases illustrate the rising trend in the demand and production levels.

Groundwater Wells Capacity

The City currently operates 31 wells in the Garber-Wellington Aquifer. The pumping capacity of each well varies due to local hydraulic and site conditions. Certain areas of the aquifer are able to produce more water due to a higher presence of sands near the well rather than the presence of shales. The wells range in pumping capacity from about 120 gpm to about 260 gpm.

TABLE 2-14
Groundwater Well Capacities

Well No.	Pumping Capacity (gpm)
1	245
2	110
3	180
4	160
5	186
6	210
7	160
8	220
10	122
11	110
12	141
13	133
14	108
15	125
16	140
18	143
19	162
20	125
21	150
23	174
25	100
31	208
32	190
33	300
34	306
35	190
36	230
37	240

Capacities reported in Table 2-14 are based on total volume pumped divided by well run time, as recorded in the City's Groundwater Wells Operational Logs. These values are constantly changing with the dynamic characteristics of the aquifer affecting pumping, including well interference, lowering of the static water level, and decreasing pressure. At the time of this writing, complete annual pumping records did not exist for the three most recently completed City wells.

Considering only the estimated pump capacities for each well, the City would have the capability to pump a total of nearly 5,000 gpm, or 7.2 mgd, to the distribution system. However, pumping at this rate cannot be sustained by the aquifer. Due to the close proximity of each well site, interference will become a problem, causing pump rates to decline. Also, as the aquifer water level decreases, reduced net positive suction head, decreased pump production, and increased energy will result. Less aggressive pumping would result in more sustained pumping over the long term, as discussed in Section 2.2.3.

Groundwater Wells Condition

The wells used by the City have been properly maintained and appear to be in great working condition. Each groundwater well is contained in a well house, made of either block or brick, protecting the well head from the elements. The well house provides ventilation in the summer months, and heat in the winter months to prevent freezing and damag to pipes and/or valves. The well houses for newer wells also contain a chlorine storage room in the event that wellhead disinfection is required, pending the passage of the Groundwater Rule.

Only two of the wells still operate with shaft-driven pumps. All other wells use submersible pumps to extract the groundwater. These remaining two wells will be converted to submersible pumps within the next year. This will update older equipment and provide uniformity within the system. Annual maintenance has allowed each well site to remain in good-to-excellent working condition.

2.3.4 Water Treatment and Production Planning Capacity

Maximum-day water demand projections over the planning horizon were based on the normalized historical trend in population and water use. As determined in Section 1, Baseline Development, and subsequent workshops, the target water supply capacity for the planning horizon is the summation of projected demand and an acceptable reserve capacity to compensate for sensitivity in total population growth, service population, land availability, per capita water use, maximum-day water use, rate structures, weather, and conservation measures. A 5-year window was applied to the projected maximum-day demands to establish the targeted water production capacities (or wellhead/WTP planning capacity). Figure 2-19 presents the targeted production capacities for the planning horizon as presented in Section 1.4.4. Also depicted on the figure, for comparison to demands, are the safe yields from the City's current water production capacity. From this analysis, target water production (wellhead/WTP) capacity is projected to increase from 27 mgd in Year 2000 to 66 mgd by Year 2040.

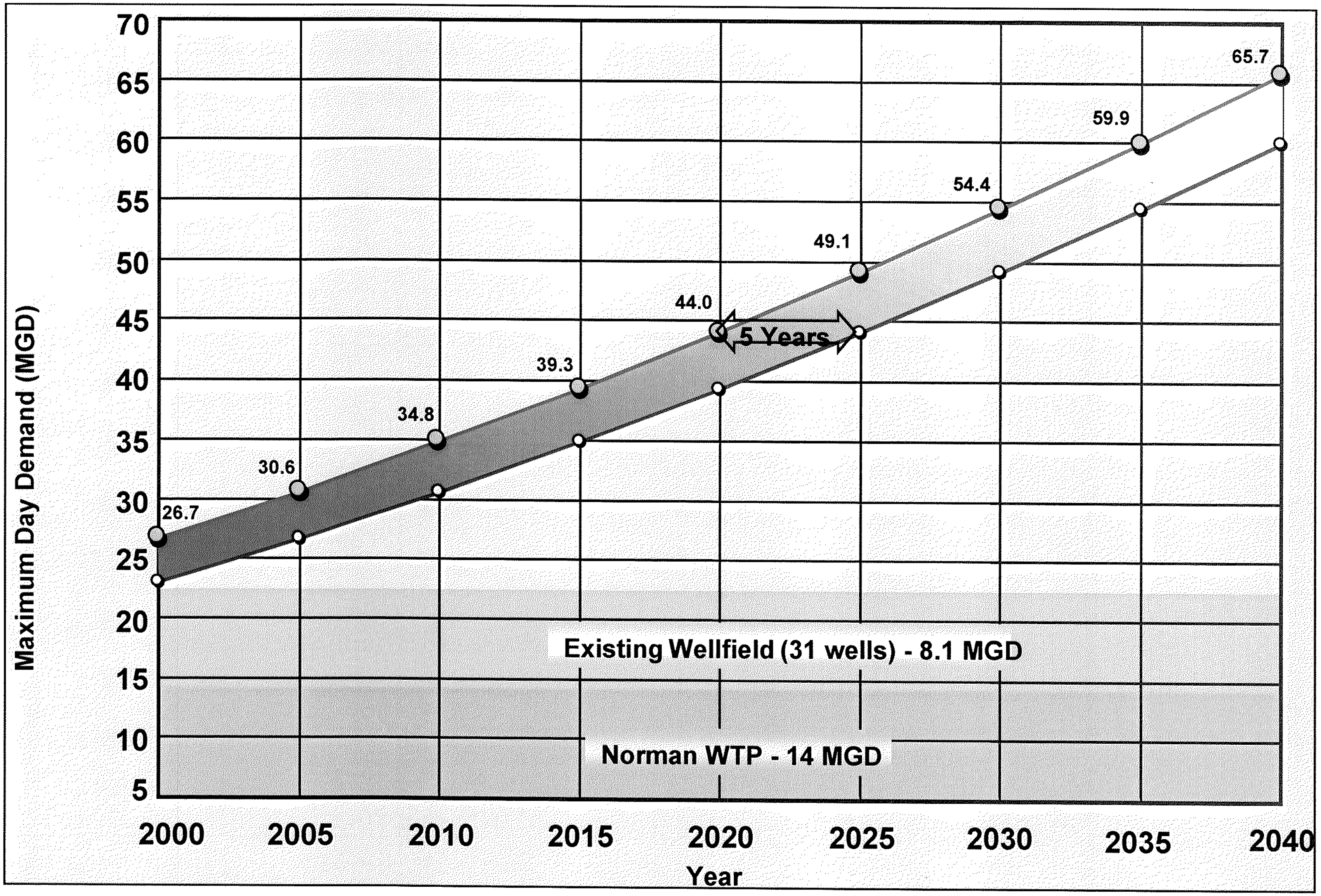


FIGURE 2-19
Existing Production Capacity and Projected Maximum Day Water Demands

2.3.5 Safe Drinking Water Act Overview

General

Water quality regulations are generally categorized on the basis of health-related or aesthetic parameters. Federal and state legislation mandates the water quality requirements necessary to meet health standards; whereas, aesthetic standards are established as recommended goals. The principle agencies involved with setting and enforcing water quality regulations that apply to the City's water production and treatment facilities are the EPA and the ODEQ.

Water quality regulations have accelerated since 1970, when an EPA survey revealed that half of the public water supply systems in the nation did not meet optimum bacterial standards. This led to increasing federal legislation and enforcement of standards. Of particular importance are the SDWA of 1974 and the SDWA Amendments of 1986 and 1996.

Legislation embodied in the SDWA provided the EPA with ultimate authority over all public water systems in the United States. A "public water system" is defined as having at least 15 service connections or regularly serving at least 25 people, 60 or more days per year. The SDWA required EPA to develop drinking water regulations with a recommended maximum contaminant level (RMCL) for contaminants that may have an adverse effect on public health. In 1975, the EPA published the National Interim Primary Drinking Water Regulations (NIPDWR). The primary regulations are federally enforceable and have since been amended with revisions promulgated in July 1976, July 1979, November 1979, April 1986, and August 1996. Additionally, SDWR concerning constituents not covered in the primary regulations were promulgated in July 1979. These secondary regulations are concerned with those contaminants that affect the aesthetic qualities of drinking water. These regulations are intended as guidelines and are not automatic rejection levels.

1986 SDWA Amendments

The 1986 SDWA Amendments expanded and accelerated the requirements of the SDWA. The major aspects of these amendments include:

- The EPA to set maximum contaminant level goals (MCLGs) and MCLs for 83 specific contaminants and for any other contaminant in drinking water that may have any adverse effect upon public health and which is known or anticipated to occur in public water systems.
- Specification of the best available technology (BAT) and monitoring requirements for the 83 contaminants.
- Filtration requirements for surface water supplies, with certain exceptions.
- Disinfection of all surface water supplies.
- Regulation of disinfection by-products.
- Prohibition of use of lead products in all conveyances for drinking water.
- Requirement for protection of groundwater sources through wellhead protection regulations.

The Amendments stipulated that the NIPDWRs, previously promulgated, become the National Primary Drinking Water Regulations (NPDWR). Furthermore, each RMCL published prior to the Amendments is now a MCLG. Since enactment of the Amendments, any NPDWR that establishes a MCL must also simultaneously publish a MCLG at the time of proposed rulemaking and promulgation.

Before the 1986 Amendments, EPA was developing water quality regulations in four phases. As a result of the 1986 Amendments, some phases were combined and renumbered. Furthermore, new regulations were added. EPA promulgated and finalized the following rules under the 1986 Amendments.

- Phase I - Volatile Organic Chemicals (VOC)
- Phase II - Synthetic Organic Chemicals (SOC) and Inorganic Chemicals (IOC)
- Phase IIA- Fluoride
- Phase V - Additional SOCs and IOCs
- Lead and Copper Rule
- Total Coliform Rule (TCR)
- Surface Water Treatment Rule (SWTR)

These rules and regulations set MCLGs and MCLs that are now encompassed in the NPDWR. States with primacy, such as Oklahoma, also published comparable state regulations as required by the Amendments. Appendix B Table B-1 summarizes the NPDWR.

A review of EPA's Safe Drinking Water Violation Report indicated that the City's water system has exceeded NPDWR on three separate events from 1993 through 1998:

- Once for the Surface Water Treatment Rule (December 1993)
- Once for the Total Coliform Rule (October of 1996)
- Once for Arsenic (January of 1998)

Details regarding each noted event are provided in the following applicable section. Notably, the most significant concern from these events is the arsenic issue. The other two noncompliance reports appear to be for isolated events, as conversations with City operations staff and a review of available water quality data (provided in Appendix B) indicate that the City's existing water system maintains compliance with all SDWA regulations established under the original rule and the 1986 Amendments. With this considered, the assessment of potential regulatory impacts to the City will focus on the 1996 SDWA Amendments. The 1996 Amendments are discussed in the following section.

1996 SDWA Amendments

The 1996 SDWA Amendments were signed into law in August 1996. Typical provisions (or anticipated provisions) of the various EPA water quality regulations under the 1996 SDWA Amendments, that are relative to the Strategic Water Supply Plan, are summarized in the following sections. In particular, the provisions to be discussed apply to public water systems serving at least 10,000 persons and using conventional treatment (i.e., coagulation, flocculation, sedimentation and filtration) for a surface water source. Information is also included on the GWR since the City currently relies on groundwater as well as surface water as a drinking water source. The following current and anticipated water quality regulations are discussed:

- Stage 1 Disinfectants/Disinfection Byproducts Rule
- Stage 2 Disinfectants/Disinfection Byproducts Rule (Stage 2 D/DBPR)
- Interim Enhanced Surface Water Treatment Rule (IESWTR)
- Long-Term 1 Enhanced Surface Water Treatment and Filter Backwash Rule (LT1FBR)
- Long-Term 2 Enhanced Surface Water Treatment Rule
- Groundwater Rule
- Arsenic Rule
- Sulfate Rule
- Radon Rule and Other Radionuclides

For each regulation, discussion is organized to provide a brief overview of the rule, a summary of the provisions (or anticipated provisions) under the rule, and the current compliance status of the City's water treatment and production facilities.

2.3.6 Stage 1 Disinfectants/Disinfection Byproducts Rule

Overview

The Stage 1 D/DBPR was promulgated on December 16, 1998, (63 FR 69390) concurrently with the IESWTR (discussed in the following section). Stage 1 D/DBPR sets new limits for disinfectant byproducts as well as residual disinfectants for all public water systems (community and non-transient/non-community) that treat their water with a chemical disinfectant. Large surface water systems (systems serving 10,000 people or more), such as the City's, must comply with the new rule by January 1, 2002. Primacy agencies, such as ODEQ, may grant individual systems requiring capital improvements up to an additional two years to comply. Conversely, primacy agencies may reduce the compliance period if they deem practical.

Stage 1 D/DBPR includes maximum residual disinfectant level goals (MRDLG) and maximum residual disinfectant levels (MRDL) for chlorine, chloramines and chlorine dioxide; MCLGs and MCLs for trihalomethanes, HAA5, bromate and chlorite; and treatment technique requirements for DBP precursors. A summary of the specific requirements of each component of the regulation follows.

Provisions

Disinfection Byproducts. Prior to the D/DBPR, THMs were the only DBPs regulated under the SDWA. The MCL for TTHMs was 0.10 mg/L, based on a running annual-average of quarterly samples in the distribution system. The D/DBPR reduces this TTHM standard and regulates another class of disinfection byproducts formed by chlorination—HAA5. Specifically, Stage 1 D/DBPR includes limits for five of the known nine HAA5. In addition, the Stage 1 D/DBPR regulates two inorganic DBPs, bromate and chlorite, which are byproducts of ozone and chlorine dioxide, respectively. Table 2-15 provides the Stage 1 D/DBPR limits for DBPs.

TABLE 2-15
Stage 1 D/DBPR
MCLGs and MCLs for Disinfection Byproducts

Disinfection Byproduct	MCLG (mg/L)	MCL (mg/L)
Total Trihalomethanes (TTHM) [b]	N/A [a]	0.080
- Chloroform	0	**
- Bromodichloromethane	0	**
- Dibromochloromethane	0.06	**
- Bromoform	0	**
Haloacetic Acids - five (HAA5) [c]	N/A [a]	0.060
- Dichloroacetic acid	0	**
- Trichloroacetic acid	0.3	**
Chlorite	0.8	1
Bromate	0	0.01

Notes:
[a] N/A - Not applicable because there are no individual MCLGs for TTHMs or HAA5.
MCLG – Maximum Contaminant Level Goal.
MCL – Maximum Contaminant Level.
[b] TTHM is the sum of the concentrations of chloroform, bromodichloromethane, dibromochloromethane, and bromoform.
[c] HAA5 is the sum of the concentrations of mono-, di-, and trichloroacetic acids and mono- and dibromoacetic acids.
**EPA has not established MCLs for individual constituents of TTHM and HAA5.

The monitoring and compliance requirements pertinent to the City for DBPs are summarized in Table 2-16. These monitoring requirements are for water systems serving 10,000 or more persons and using surface water (or groundwater under the direct influence of surface water). Noticeably, Table 2-16 does not include monitoring requirements for chlorite and bromate, as monitoring is only required for systems utilizing chlorine dioxide and ozone, respectively, for oxidation/disinfection. The City currently uses chloramines for its primary and residual disinfection practice.

TABLE 2-16
Stage 1 D/DBPR
Monitoring Requirements for DBPs [a]

Disinfectant Byproduct	Monitoring	Compliance
Routine Monitoring		
Total Trihalomethanes (TTHM)	4 samples / quarter / plant [b]	Running annual arithmetic average, computed quarterly, of quarterly arithmetic averages of all samples.
Haloacetic Acid - five (HAA5)	4 samples / quarter / plant [b]	Running annual arithmetic average, computed quarterly, of quarterly arithmetic averages of all samples.

Note:
[a] For water systems using surface water or groundwater under the direct influence of surface water and serving 10,000 or more persons.
[b] One sample taken at the location representative of maximum residence in the distribution system during month of warmest temperature; three samples taken at locations representative of system variability.

Disinfectant Residuals. In addition to regulating DBPs, Stage 1 D/DBPR also set maximum allowable limits for residual disinfectants. The terms MRDL and MRDLG have been newly created with the release of the D/DBPR. The MRDLs are similar to the MCL requirements, but the term contaminant does not apply to disinfectants that are limited under the rule. The MRDLs do not limit disinfection dosage but rather disinfection residual in the distribution system. The levels are summarized in Table 2-17.

TABLE 2-17
Stage 1 D/DBPR
MRDLGs and MRDLs for Disinfectants [a]

Disinfectant Residual	MRDLG (mg/L)	MRDL (mg/L)
Chlorine (as CL_2)	4	4.0
Chloramine (as CL_2)	4	4.0
Chlorine Dioxide (as ClO_2)	0.8	0.8

Note:
[a] MRDLG – Maximum Residual Disinfectant Goal
MRDL – Maximum Residual Disinfectant Level

Compliance with the MRDL for chloramines (as well as chlorine) is based on a running annual arithmetic average of monthly averages of all samples, computed quarterly. Short-term increases for chloramines (and chlorine) are allowed for the control of specific microbiological problems in the water distribution system. Additionally, EPA believes determining compliance based on running annual averages, computed quarterly, should allow systems to increase residual disinfectant levels for a time necessary to address microbial problems and still maintain compliance.

At a minimum, systems must measure the residual disinfectant level at the same point in the distribution system and at the same time as total coliforms. Based on provisions of the TCR and ODEQ regulations, the City must perform 80 samples per month for coliforms, and hence residual disinfectant. Stage 1 D/DBPR does not allow for reduced monitoring for disinfectant residual.

Treatment Techniques. The Stage 1 D/DBPR requires surface water systems using conventional treatment or precipitative softening (the City's WTP practices lime softening) to remove DBP precursors, and thereby reduce DBPs, by enhanced coagulation or enhanced softening. TOC, a surrogate parameter of DBP precursors, is an indicator to measure DBP precursor removal performance. Systems failing to meet one of six specified exemption criteria are required to provide from 15 to 50 percent TOC removal, depending on the raw water TOC and alkalinity. The rule also includes alternate performance criteria for systems that can not reasonably meet the specified TOC removal.

The final Stage 1 D/DBPR requires water systems to meet the TOC removals (between the source water and the combined filter effluent) shown in Table 2-18 by enhanced coagulation or enhanced softening unless one or more of the following conditions applies.

- The system's source water TOC is 2.0 mg/L or less.
- The system's treated water TOC is 2.0 mg/L or less.
- TOC concentration in the raw water is less than 4.0 mg/L, alkalinity is greater than 60 mg/L, and TTHMs and HAA5 in the treated water are less than 0.040 mg/L and 0.030 mg/L, respectively, with any disinfectant, or the water system has made a clear and irrevocable financial commitment to technologies that will limit the levels of TTHMs and HAA5 in the distribution system to less than 0.040 mg/L and 0.030 mg/L, respectively.
- TTHMs and HAA5 in the treated water are less than or equal to 0.040 mg/L and 0.030 mg/L, respectively, with disinfection by chlorine only.
- Specific ultraviolet absorbance at 254 nanometers (SUVA) in the system's source water, prior to any treatment, is 2.0 L/mg-m or less.
- SUVA in treated water is less than or equal to 2.0 L/mg-m, where SUVA is measured on water prior to the addition of disinfectants or oxidants. (Bench-scale testing is required for plants that add disinfectants or oxidants prior to the treated water sampling point.)

Compliance with the enhanced coagulation and enhanced softening requirements is calculated quarterly as a running arithmetic annual-average based on monthly monitoring for TOC, alkalinity, and SUVA or quarterly monitoring for TTHMs and HAA5s.

TABLE 2-18
Stage 1 DBPR
Requirements for TOC Removal [a]

Source Water TOC	Source Water Alkalinity (mg/L as $CaCO_3$)		
(mg/L)	0 – 60	> 60 – 120	> 120 [b]
>2.0 - 4.0	35%	25%	15%
>4.0 -8.0	45%	35%	25%
>8.0	50%	40%	30%

Note:
[a] Percent removal is between raw water and combined filter effluent.
[b] Systems practicing softening must meet the TOC removal requirements in this column.

As previously mentioned, the rule provides respective alternative performance criteria for systems practicing enhanced coagulation or enhanced softening that cannot feasibly meet the TOC removal requirements discussed above. For enhanced coagulation systems, jar tests are used to determine alternative TOC removal percentages. For softening systems, additional alternative compliance criteria include:

- Magnesium hardness removal of at least 10 mg/L as $CaCO_3$; or
- Treated water with an alkalinity of less than 60 mg/L as $CaCO_3$

Compliance with the above alternative criteria for softening systems is based on running arithmetic annual-average, computed quarterly.

Norman System Compliance Status

Based on historical water quality data for TTHMs, the City's finished water is well within compliance of the 0.080 mg/L MCL for TTHMs set under the D/DBPR. Figure 2-20 summarizes the running annual-average TTHM concentration (computed quarterly) in the City's finished water.

Noteworthy, compliance with the TTHM standard is attributable to the City's chloramine disinfection practice, which began in the mid 1980s. Prior to 1983, the City used free chlorine for its primary disinfectant and TTHM levels averaged well above 0.10 mg/L (TTHM standard prior to the Stage 1 D/DBPR). However, current TTHM average levels are now typically less than 0.020 mg/L and consistently less than 0.030 mg/L.

Prior to the D/DBPR, the City did not monitor finished water for HAA5 levels, as these DBPs were not regulated. With the promulgation of the D/DBPR, City staff monitored one raw and one finished water sample for HAA5 levels. Results from this monitoring event are presented in Table 2-19.

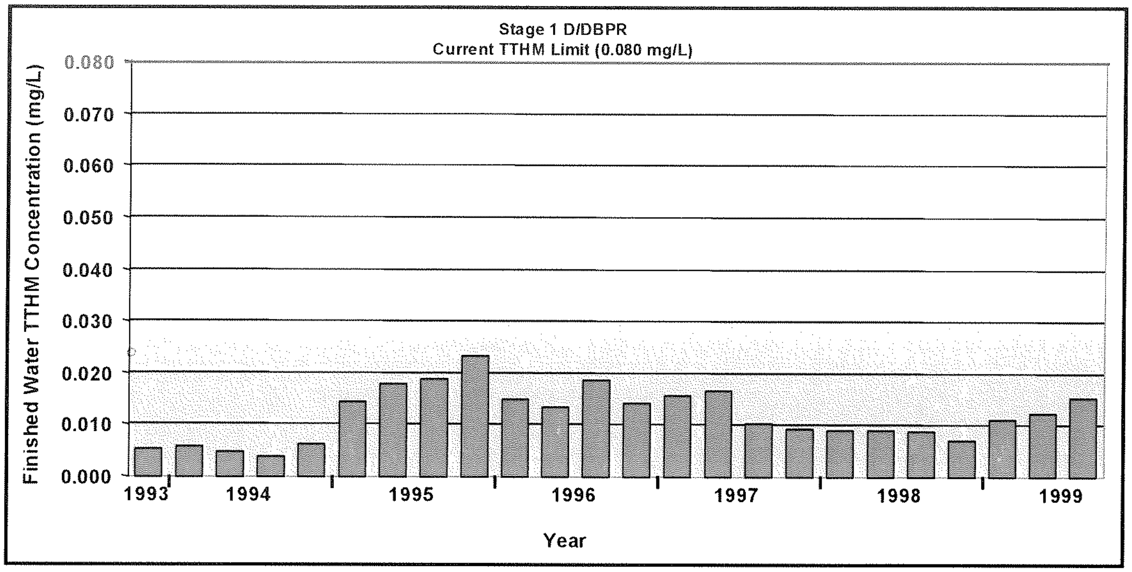


FIGURE 2-20
Finished Water Running Annual Average TTHM Concentration

TABLE 2-19
Raw and Finished Water HAA5 Levels [a]

Source	HAA5 (mg/L)
Raw Water (at WTP)	< 0.035
Finished Water (at WTP)	< 0.024
EPA Standard (MCL)	**0.060**

Note:
[a] Represents one sampling event on March 11, 1999.

Based on the monitoring data shown in Table 2-19, the City's finished water is in compliance with the 0.060 mg/L HAA5 MCL. The raw water HAA5 level is shown simply to demonstrate the quantity removed through the treatment process. However, the data set is incomplete to determine full compliance status, as compliance is based on running annual-averages (computed quarterly) of quarterly samples (four samples per quarter for the City) taken out in the distribution system. It is advisable that the City update and continue with the already initiated HAA5 and TOC monitoring program.

City staff has initiated a target total chlorine disinfectant residual of 2.8 mg/L at the WTP. Based on archive finished water quality data for the WTP, the running annual-average level ranges from 2.4 to 2.55 mg/L. Additionally, based on the running annual-average of monthly total chlorine residual monitoring, the total chlorine residual in the distribution system ranges from 1.07 to 1.33 mg/L. As such, the City is in compliance with the MRDL under this rule. Table 2-20 summarizes the disinfectant residuals at the WTP and in the distribution system.

TABLE 2-20
Disinfectant Residuals [a]

Criteria	Total Chlorine Residual (mg/L) WTP	Total Chlorine Residual (mg/L) Distribution System
Maximum	2.55	1.33
Average	2.47	1.12
Minimum	2.40	1.07
EPA Standard (MRDL)	**4.0**	**4.0**

Note:
[a] Data summarizes running annual averages of monthly averages for 1993 through 1998.

Table 2-21 summarizes the level of treatment provided at the WTP pertinent to the treatment techniques identified under the Stage 1 D/DBPR. Current plant operation procedures add chloramines upstream of the upflow clarifiers, the first treatment process, to provide a maximum disinfectant contact time. Based on the reported data, it is expected the WTP will need to remove 25 percent of the TOC by enhanced coagulation or enhanced softening, unless satisfying one of the alternative treatment criteria for finished water alkalinity or magnesium hardness is possible through modification of the lime softening process. A higher chloramine dose and/or changing of the disinfectant location may also aid in the treatment process. Although the available TOC data represents only a one-time sampling event, it does suggest non-compliance issues ahead. The City should implement a TOC monitoring program to better assess the potential challenges that lie ahead and methods to address these challenges.

TABLE 2-21
TOC, Alkalinity, and Magnesium Hardness WTP Data

Parameter	Raw Water	Finished Water
TOC (mg/L) [a]	6.6	5.9
Total Alkalinity (mg/L as $CaCO_3$) [b]	153.2	78.2
Magnesium Hardness (mg/L as $CaCO_3$) [b]	38.4	67.0

Note:
[a] Data from one sample collected on March 11, 1999
[b] Average of daily samples from June 1993 through June 1998

2.3.7 Stage 2 Disinfectants/Disinfection Byproduct Rule

Overview

The EPA intends to link the implementation schedules for Stage 2 D/DBPR and Long Term-2 ESWTR to balance the risks associated with simultaneously treating water to control microbial contaminants, disinfectants and DBPs. At present, Stage 2 D/DBPR is scheduled to be finalized by May 2002. Affected water systems will have 36 months to comply after promulgation of the regulation. Primacy agencies may allow an additional 24 months for compliance by water systems requiring capital improvements. Conversely, primacy agencies may reduce the compliance period if they deem practical.

Provisions

The D/DBPR proposed on July 29, 1994 (59 FR 38668) included Stage 2 MCLs for TTHMs (0.04 mg/L) and HAA5 (0.03 mg/L) for water systems serving at least 10,000 persons and using surface water. The EPA will establish the final Stage 2 MCLs after reviewing data furnished under the Information Collection Rule, results of new health effects research and other information developed since the proposal of the Stage 2 MCLs.

Norman System Compliance Status

As previously mentioned, the TTHM and HAA5 MCLs under the Stage 2 D/DBPR are not yet finalized and therefore could change from the July 1994 proposed limits. Considering the water quality data reported, the City can meet the proposed Stage 2 TTHM MCL. Based on HAA5 sampling in March 1999, the potential exists that the City may not be able to fully meet the Stage 2 HAA5 limit with current disinfection practices.

2.3.8 Interim Enhanced Surface Water Treatment Rule

Overview

The Interim Enhanced Surface Water Treatment Rule (IESWTR) was promulgated along with the Stage 1 D/DBPR on December 16, 1998 (63 FR 69478). The primary purposes of the Interim ESWTR are:

- Improve control of microbial pathogens in drinking water, particularly for the protozoan *Cryptosporidium*; and
- Guard against significant increases in microbial risk that might otherwise occur when systems implement the Stage 1 D/DBPR.

The final Interim ESWTR applies to public water systems that use surface water or groundwater under the direct influence of surface water and serve 10,000 or more people. Such systems generally have until December 17, 2001, to comply with the provisions of the final rule, except for profiling and benchmarking which require certain systems to begin sampling for TTHMs and HAA5 within three months (by March 16, 1999). Similar to the D/DBPR, systems that require capital improvements may be granted up to two additional years to comply. In addition to requirements for systems serving 10,000 or more people, the rule requires primacy agencies, such as ODEQ, to conduct sanitary surveys for all surface water and groundwater under the direct influence of surface water systems regardless of size.

Provisions

Major provisions of the Interim ESWTR include the following.

- Revises the definition of "groundwater under the direct influence of surface water" to include *Cryptosporidium*.
- Establishes a MCLG of zero for *Cryptosporidium*.
- Requires a 2-log (99 percent) removal of *Cryptosporidium* for water systems that are required to filter under the SWTR. Systems using conventional or direct filtration meet this requirement if they comply with the SWTR and with the turbidity standards and disinfection profiling and benchmarking under the Interim ESWTR (discussed below).
- *Cryptosporidium* is added to the watershed protection program for unfiltered systems.
- Requires states to perform periodic sanitary surveys for all public water systems (regardless of size) that use surface water or groundwater under the direct influence of surface water. For community systems, sanitary surveys are required at least every three years. However, for community systems that have outstanding performance, as determined by the primacy agency and prior surveys, the frequency may be reduced to once every five years.
- Water systems must cover all finished water storage tanks and reservoirs for which construction begins after February 16, 1999. In other words, finished water storage facilities must be constructed so that finished water is not exposed to potential contamination.

Turbidity Control. In addition to the provisions mentioned above, the Interim ESWTR includes several requirements for filtration performance and filter monitoring and reporting. In general, these requirements use turbidity to assess performance in providing microbial protection. The Interim ESWTR requires water systems to meet the following turbidity requirements.

- The combined filtered water turbidity must be less than or equal to 0.3 NTU in at least 95 percent of the monthly samples.
- The combined filtered water turbidity must never exceed 1 NTU. Compliance with the combined filtered water turbidity requirements is based on sampling at 4-hour intervals.

In addition, the Interim ESWTR requires water systems using conventional treatment or direct filtration to provide continuous turbidity monitoring of each individual filter and report the following to the primacy agency (ODEQ) on a monthly basis.

- Any individual filter with a turbidity greater than 1.0 NTU on two consecutive measurements, 15 minutes apart
- Any individual filter with turbidity greater than 0.5 NTU at the end of the first four hours of filter operation, based on two consecutive measurements 15 minutes apart

A filter profile must be provided to the primacy agency within seven days if the water system cannot identify an obvious reason for the abnormal filter performance.

In addition, if an individual filter exceeds 1.0 NTU filtered water turbidity, based on two consecutive measurements taken 15 minutes apart at any time in each of three consecutive months, the system must report the exception to the primacy agency and conduct a self-assessment of the filter. If an individual filter turbidity exceeds 2.0 NTU, based on two consecutive measurements taken 15 minutes apart at any time in each of two consecutive months, the system must report the exception and arrange for a comprehensive performance evaluation by the agency or by a third party approved by the state.

Disinfection Benchmark. The Interim ESWTR requires water systems to prepare a "disinfection profile" if:

- Annual average TTHMs in the treated water are 0.064 mg/L or more; or
- Annual average HAA5 in the treated water are 0.048 mg/L or more.

The disinfection profile is to be based on daily monitoring conducted over a one- to three-year period. The disinfection profile must include historical inactivations of *Giardia lamblia* and, for systems using chloramines or ozone, viruses. Daily measurements of disinfectant residual, disinfectant contact time, water temperature, and pH (where necessary) are required.

Water systems that are required to prepare a disinfection profile must consult with the primacy agency before making one or more of the following changes to their disinfection strategy.

- Moving the disinfectant application point
- Changing the type of disinfectant
- Changing the disinfection process
- Making any other change deemed significant by ODEQ

The rule requires that profiling data begin no later than 15 months after promulgation of the Interim ESWTR (by March 2000). As such, monitoring for TTHMs and HAA5 must be completed by March 2000, unless the system elects to proceed directly to profiling.

Norman System Compliance Status

The combined filter water quality for June 1993 through June 1998 is provided in Appendix B. Based on these data, the combined filter water turbidity ranged from 0.27 NTU to 0.04 NTU, with an overall average of 0.08 NTU. The City is currently in compliance with the combined filter water standards under the Interim ESWTR.

The City recently installed a turbidimeter on each filter cell that records filter performance on a continuous basis. Individual filter performance data from September through October 1999 was available for review. Filter performance does vary over any given day, more than likely due to filter ripening following backwash cycles and flow variation to the filters caused by varying WTP flow, backwashing adjacent filters, and flow variation from the upflow clarifiers. Nevertheless, based on the reviewed data, the City is in compliance with the individual filter water quality standards. Figure 2-21 provides a sample window depicting filter performance for Filter No. 1 on October 14, 1999.

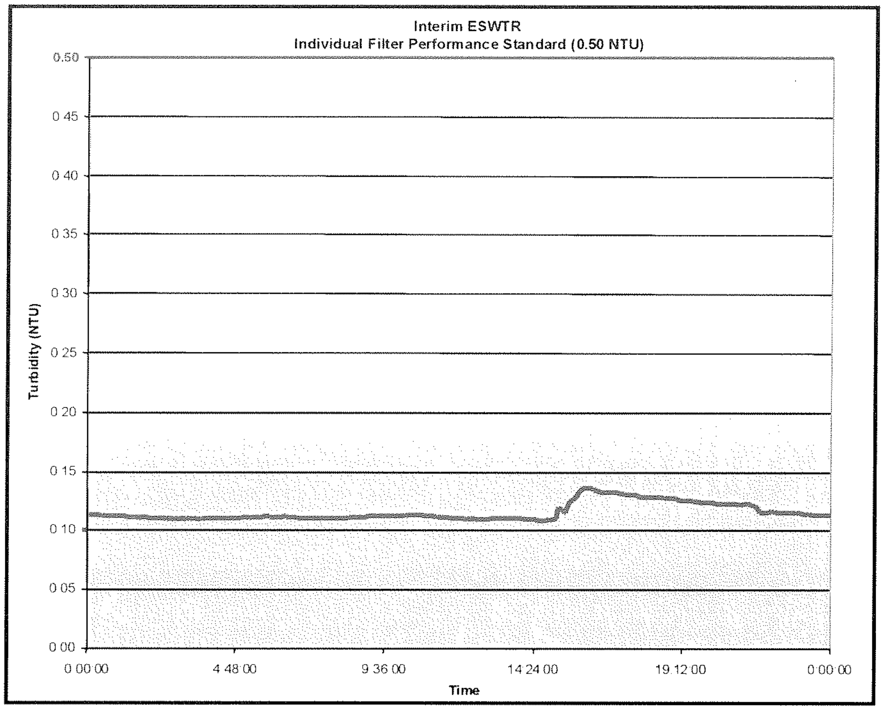


FIGURE 2-21
Individual Filter Performance
Sample Window – Filter No. 1 Performance on October 14, 1999

2.3.9 Long-Term 1 Enhanced Surface Water Treatment and Filter Backwash Rule

Overview

The EPA intends to combine the second part of the Enhanced Surface Water Treatment Rule (ESWTR) (i.e., Long-Term 1) and the Filter Backwash Rule (FBR) in a single rule—Long-Term 1 Enhanced Surface Water Treatment and Filter Backwash Rule (LT1FBR). At present, LT1FBR is scheduled to be proposed in late 1999 and promulgated in August 2000. Affected water systems will have 36 months to comply after promulgation of the regulation. Primacy agencies may allow an additional 24 months for compliance by water systems requiring capital improvements. Conversely, primacy agencies may reduce the compliance period if they deem practicable.

Provisions

Based on a preliminary draft preamble to the rule (distributed by EPA on June 1, 1999), many of the provisions of LT1FBR will apply only to public water systems using surface water or groundwater under the direct influence of surface water and serving fewer than 10,000 persons. These provisions, which will improve control of microbial pathogens in drinking water and prevent increases in microbial risk while systems comply with Stage 1 D/DBPR, do not apply to the City of Norman and, therefore, are not discussed further. The only provision of LT1FBR, based on the rule's preliminary preamble, that may apply to the City is a requirement that systems using surface water or groundwater under the direct influence of surface water return all recycle flows to the head of the plant (i.e., prior to chemical rapid mix).

Norman System Compliance Status

Essentially, the majority of the provisions under this rule will not apply to the City, as the City's service population is greater than 10,000. Also, with the WTP's existing treatment process train, the recycle flow is currently introduced prior to the three upflow clarifiers, and hence prior to coagulant, lime, and polymer chemical addition. However, we recommend that the City continue to monitor the development of this rule, specifically provisions of the filter backwash rule, and confirm compliance when the rule is proposed and promulgated.

2.3.10 Long-Term 2 Enhanced Surface Water Treatment Rule

Overview

The EPA intends to link the implementation schedules for LT2ESWTR and Stage 2 D/DBPR to balance the risks associated with simultaneously treating water to control microbial contaminants, disinfectants and DBPs. At present, LT2ESWTR is scheduled to be finalized by May 2002. Affected water systems will have 36 months to comply after promulgation of the regulation. Primacy agencies may allow an additional 24 months for compliance by water systems requiring capital improvements. Conversely, primacy agencies may reduce the compliance period if they deem practicable.

Provisions

The EPA will consider data furnished under the Information Collection Rule, new health effects research and other information not available during prior rulemaking to develop LT2ESWTR. Of greatest concern will be the necessity to augment microbial protection from *Giardia lamblia*, *Cryptosporidium* and viruses. The EPA will likely revisit the alternative treatment levels identified in the proposed IESWTR (59 FR 38832, July 29, 1994), which ranged as great as **99.9999 percent (6-log)** removal and/or inactivation for each of the pathogens.

Norman System Compliance Status

As previously mentioned, promulgation of the LT2ESWTR is scheduled for May 2002, and therefore, provisions under the rule are not yet well defined. However, if removal and/or inactivation requirements become more stringent, this rule has the potential of impacting the City's WTP. Currently, under the SWTR, EPA allows credit for 2.5-log removal of *Giardia* cysts and 2-log removal of viruses for well-designed and operated water treatment plants using conventional treatment. Hence, for a conventional WTP such as the City's, the primary disinfection process must achieve at least 0.5-log inactivation of *Giardia* cysts and 2-log inactivation of viruses. Considering the City's Disinfection Study (from 1993), the City's current chloramine disinfection practice requires contact time through the entire treatment process train to meet these disinfection requirements under the SWTR. Noteworthy, the City converted to using chloramines for its disinfection practice due to the high levels of TTHMs in the finished water with the use of free chlorine, as practiced prior to 1983. Additionally, the City, historically and currently, has been able to achieve great success in controlling TTHM formation in its finished water with the use of chloramines. With these considered, if the removal and/or inactivation provisions become more stringent under the LT2ESWTR, modifications to the City's current disinfection practice and/or treatment process train may be warranted in the future. Depending on the requirements of the LT2ESWTR, modifications could include increasing chloramine residual, adding baffles to the existing clearwells, additional clearwell volume, and/or conversion to a more powerful disinfectant/oxidant (such as ozone). Furthermore, treatment processes to remove TOC may be necessary if they are not implemented as a result of other pending regulations.

2.3.11 Groundwater Rule

Overview

As required under the 1996 SDWA Amendments, EPA is developing a rule, which specifies the appropriate use of disinfection and, just as importantly, addresses other components of groundwater systems to ensure public health protection. EPA initially planned to develop the Groundwater Disinfection Rule concurrently with the proposed Stage 1 D/DBPR. Since that time, EPA has renamed the Groundwater Disinfection Rule to the GWR to emphasize their focus on non-disinfection options. The GWR is expected to be proposed in Spring 2000 and finalized in May 2002.

Provisions

In January 1999, EPA released a Draft Preamble to the GWR, which requested comments on the proposed requirements of the rule. Provisions of GWR that EPA is proposing and requesting comments include:

Sanitary Surveys. EPA proposes to require primacy agencies or a state-authorized third party to conduct sanitary surveys at least every three years. Additionally, agencies, as a condition of primacy, would have to develop a plan to identify high priority groundwater systems. Sanitary surveys for these systems would have to be completed within the first two years of the three-year monitoring cycle. Systems would be required to correct any deficiencies (as determined by ODEQ), or provide a schedule for correcting deficiencies, within 90 days of receiving the results of the survey. If the deficiency cannot be corrected, systems would be required to provide 4-log (99.99 percent) virus removal/inactivation.

Hydrogeologic Sensitivity Assessment. EPA proposes that the primacy agency conduct a one-time sensitivity assessment of all systems that do not treat to 4-log virus inactivation. Any systems determined to be sensitive would be required to monitor for EPA-specified fecal indicators on a monthly basis for one year. Within six months of any positive source water sample, where the primacy agency does not determine the problem is corrected, the system would have to provide: (1) treatment of the groundwater, or (2) provide an alternative source of safe water. The sensitivity assessment must be completed for all groundwater systems within three years of promulgation of the GWR.

Source Water Monitoring. EPA proposes the following source water monitoring criteria:

- At least one source water sample following a total coliform-positive sample under the TCR; and
- Monthly monitoring for any system which does not provide disinfection that has a hydrogeologically sensitive groundwater source.

Treatment. EPA proposes that systems with deficiencies (determined through sanitary surveys, hydrogeologic sensitivity assessment, or source water monitoring) that are not or cannot be corrected and alternative sources of drinking water are not available provide 4-log inactivation/removal of viruses. The proposed compliance schedule is 6-months after receiving a positive fecal-indicator groundwater sample. EPA proposes two treatment techniques: (1) disinfection with chlorine, or (2) disinfection with an alternative disinfectant or treatment. Systems practicing chlorine disinfection would be required to provide at least 0.2 mg/L residual chlorine prior to the point of entry into the distribution system and maintain a chlorine residual throughout the distribution system. EPA would consider such systems as providing 4-log inactivation of viruses. For systems practicing alternative disinfection methods (use of chlorine dioxide, ozone, mixed oxidants, UV, or chloramines), 4-log inactivation would be determined by disinfection contact times (CT) values. Alternatively, EPA recognizes physical removal techniques—membrane processes.

Norman System Compliance Status

Currently, water quality from the City's existing wellfield is of such high quality, that water is pumped directly into the distribution system. If, under the GWR, the City is required to provide disinfection, significant changes to the operation of the wellfield will likely be necessary. For example, meeting disinfectant contact times at each wellhead will be difficult to achieve, especially with the use of chloramines, which is the current disinfectant residual practiced by the City. Therefore, disinfection may have to be provided at a common facility or facilities that collects and detains the well water to ensure proper contact times are achieved prior to distribution. Additionally, the use of chlorine disinfectant at the wellhead may be limited, as mixing of dissimilar disinfectant residuals in the distribution system is not recommended due to the difficulty in maintaining minimum required disinfectant residuals and the consequential taste and odor problems. In any event, if a wellhead disinfection practice is required, chemical feed facilities and associated chemical purchase requirements and facility maintenance needs would be newly added to the City's current system and operation practice. Also, any new wells developed in the unconfined recharge zone of the Garber-Wellington Aquifer are susceptible to a "sensitive" classification. Consequently, wellhead or common groundwater disinfection would be required.

2.3.12 Arsenic

Overview

The current MCL for arsenic, which was established as part of the NIPDWR in 1975, is 50 μg/L. A new MCL was expected in 1993. However, because of controversies with nearly all aspects of the rulemaking process—health effects, occurrence data, treatment technologies, implementation costs, and analytical methods—a new arsenic rule is still pending.

Provisions

The 1996 SDWA Amendments require the EPA to propose an arsenic rule by January 2000 and promulgate the rule by January 2001. The new arsenic MCL is expected to be in the range of 2 to 20 μg/L. Preliminary indication from EPA is that the new Arsenic MCL will be set at 10 μg/L.

Norman System Compliance Status

Review of available groundwater quality data (provided in Appendix B) shows that the City is in compliance with the current MCL of 50 μg/L. However, Well No. 23 has an average arsenic concentration very close to the MCL, at 46 μg/L. Additionally, based on available data, it is anticipated that Well Nos. 4, 7, 11, 14, 15, 16, 18, 21, and 23 will exceed the potential future MCL of 20 μg/L. Should the MCL be set at 5 μg/L, Well No. 2 will also be in violation and require additional treatment. In addition to these wells, Well Nos. 5, 8, and 20 would exceed the potential future MCL if it were set at 2 μg/L. Further testing and analysis of arsenic levels at the well sites is suggested because this data set is small.

2.3.13 Sulfate

Overview

Currently sulfate is regulated as a secondary contaminant—that is, a contaminant that may affect the aesthetic quality of drinking water. EPA established a secondary MCL of 250 mg/L as part of the National Interim Secondary Drinking Water Regulations (NISDWR) in 1975.

In December 1994, EPA proposed a primary MCL of 500 mg/L for sulfate. The proposed regulation provided an alternate to MCL compliance by allowing water systems to comply through a public education/notification and bottled water program. In light of uncertain implementation costs, inadequate health data, and pending reauthorization of the SDWA, the final sulfate rule was not promulgated in May 1996 as originally scheduled. In February 1999, EPA, in conjunction with the Centers for Disease Control, completed a study assessing the health effects of sulfate. The results of this study will be used to determine if sulfate should be regulated.

Provisions

The 1996 SDWA Amendments require EPA to determine whether to regulate sulfate by August 2001. If EPA decides to regulate sulfate, the sulfate rule must be reproposed by August 2003 and promulgated by February 2005.

Norman System Compliance Status

Review of the sulfate concentrations in the finished water from the WTP and available data from the groundwater wells (provided in Appendix B), indicates the City is well in compliance with the current Secondary MCL of 250 mg/L for sulfate. Hence, the City will be in compliance with the December 1994 proposed Primary MCL of 500 mg/L, if EPA decides to finalize this proposed limit.

2.3.14 Radon and Other Radionuclides

Overview

EPA proposed radionuclide standards in July 1991 to revise the standards established as part of the NIPDWR in 1975 and to regulate additional contaminants. In August 1997, EPA withdrew the proposed MCL for radon, as required by the 1996 SDWA Amendments. These current and proposed radionuclide standards are summarized in Table 2-22.

TABLE 2-22
Current and Proposed MCLs for Radionuclides

Contaminant	Current MCL	Proposed MCL
Radon	None	None
Radium 226	5 pCi/L [a], [b]	20 pCi/L
Radium 228	5 pCi/L [b]	20 pCi/L
Uranium	None	20 g/L
Adjusted Gross Alpha Emitters	15 pCi/L	15 pCi/L
Gross Beta and Photon Emitters	4 mrem/yr [c]	4 mrem/yr

Note:
[a] pCi/L = Picocurie per liter, a measure of the disintegration of a radionuclide.
[b] MCL is combined total of Radium 226 and Radium 228.
[c] mrem/yr is a measure of the dose effect of radiation.

The 1996 SDWA Amendments address radon but none of the other radionuclides. The Amendments require EPA to propose and promulgate a radon standard after a risk assessment study has been completed by the National Academy of Sciences. The risk assessment was completed in February 1999. The target schedule for the proposed and promulgated Radon Rule is August 1999 and August 2000, respectively. However, the August 1999 proposal deadline has slipped. The new MCL for radon is expected to be 300 pCi/L for groundwater systems serving more than 10,000 people. It is anticipated that the proposed MCL will only apply to groundwater systems.

Although radionuclides other than radon are not addressed in the 1996 SDWA Amendments, their regulation remains subject to court-negotiated deadlines. The EPA has agreed to repropose and promulgate standards for uranium by late 2000. At the same time, the EPA must either set standards for the remaining radionuclides or publish a notice of nonregulation.

Norman System Compliance Status

Water quality data for radon and radionuclides for finished water from the WTP and groundwater produced from the City's wells was not available to ascertain compliance status. However, based on data reported in the City's Master Water Plan (October 1992), Well Nos. 12, 21, and 25 have, at least in the past, exceeded the Gross Alpha MCL. Additionally, Well No. 21 has exceeded the Gross Beta MCL.

2.3.15 Norman System Regulatory Impact Assessment Summary

Each of the new regulations proposed by EPA may affect the City in their operational procedures in producing safe drinking water. Table 2-23 summarizes the potential impacts of each regulation on the City. Additionally, Figure 2-22 provides a tentative compliance schedule for each of the proposed future regulations.

TABLE 2-23
Norman System Regulatory Impact Assessment

Regulation	Effective Date	Potential Required Action
D/DBP Rule – Stage 1	Nov 2001	Removal of HAA5 pending additional data. Reduction in TOC using enhanced coagulation or enhanced softening.
D/DBP Rule – Stage 2	May 2005	Further reduction of TTHM and/or HAA5 concentrations pending rule development.
IESWTR	Nov 2001	No action necessary at this time.
LT1FBR	Aug 2003	No action necessary at this time.
LT2ESWTR	May 2005	Increased chlorine residual, baffled clearwells, additional clearwell volume, and/or conversion to a more powerful disinfectant.
GWR	May 2005	Wellhead or common disinfection.
Arsenic	Jan 2004	Treatment to reduce arsenic concentration of high Arsenic level wells.
Radon & Radionuclides	Aug 2003	Increase data set to review for potential necessary improvements.

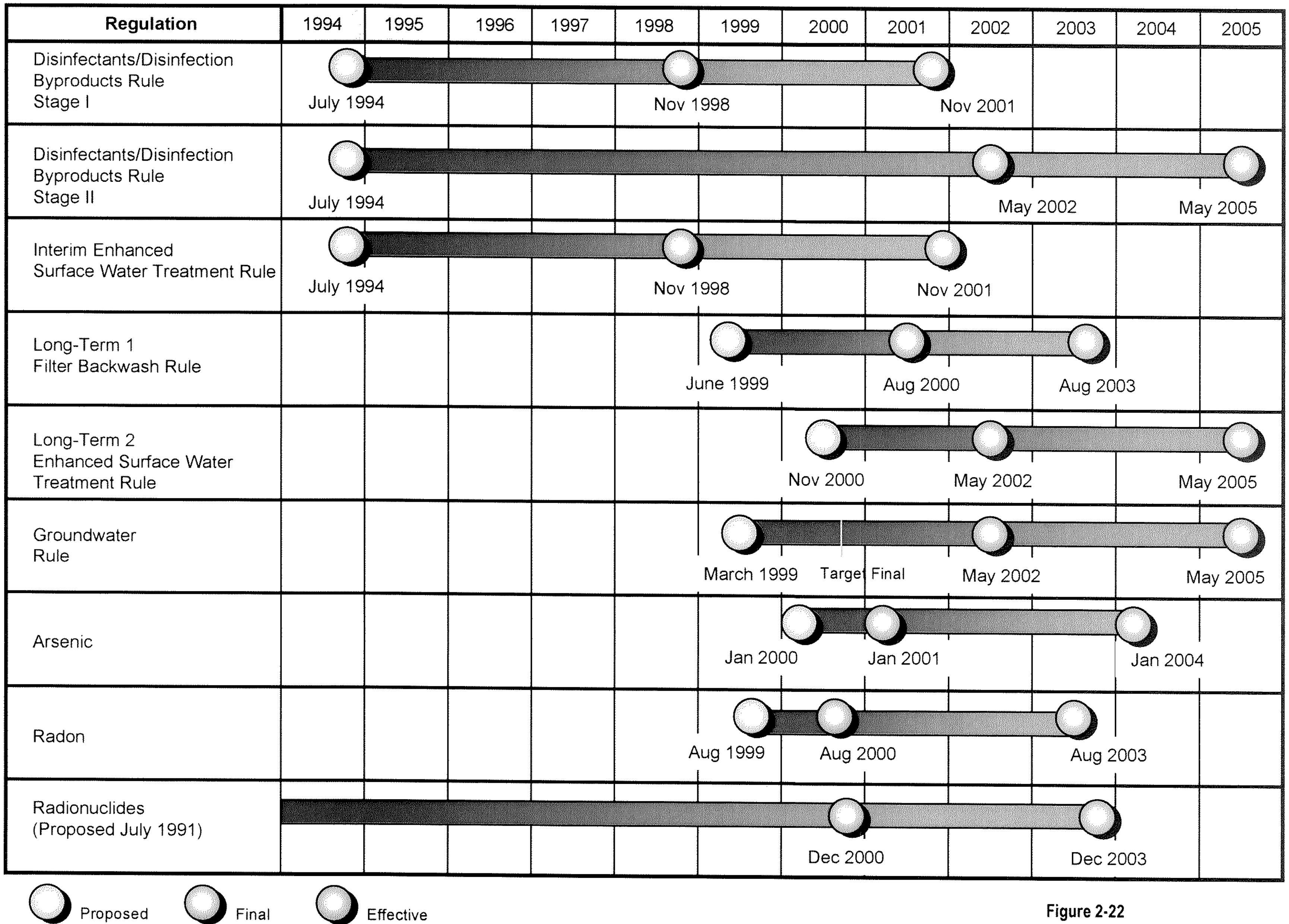


Figure 2-22
Safe Drinking Water Act
Compliance Schedule

3. Alternatives Evaluation

3.1 Introduction

3.1.1 General

Baseline development and existing system assessment findings reported in previous sections were used as the basis in preparing a long-list of 17 water supply options for evaluation. A short-list of six water supply plan alternatives was then developed that offer the greatest potential and most cost-effective means for securing a safe and reliable supply to meet the City's projected water demands through the planning horizon. The evaluation of water resources included quality and quantity, availability, likely implementation window, and development of conceptual acquisition costs for securing water rights. From this evaluation, a short-list of water resource options was generated and considered for further development under the water supply plan. Required conveyance, treatment, and production subsystem infrastructure options and conceptual costs were identified and developed for each of the short-list options.

Presented herein is an evaluation of each water resource alternative and associated conveyance, treatment, and production subsystem considered for the planning horizon. The methodologies or rationale used to assemble the short-listed resources into plan alternatives are presented, as well as monetary factors generated for each alternative. Non-monetary factors used to perform a matrix analysis of the water supply plan alternatives are also defined. A matrix analysis of monetary and non-monetary factors is utilized to select the recommended strategic water supply plan to meet the City's needs through the planning horizon.

3.1.2 Section Organization

Discussion of alternatives and evaluation criteria is presented in the following sections.

- Section 3.2 Long-List (Water Resources) Evaluation
- Section 3.3 Short-List (Water Resources) Development
- Section 3.4 Plan Alternatives Analysis

3.2 Long-List (Water Resources) Evaluation

3.2.1 General

The City of Norman currently satisfies water consumption demands through two water resources—Lake Thunderbird and the GWA. These two resources were characterized in Section 2, Existing System Assessment. Combined, these two resources provide the City with a sustainable yield of 12.6 mgd on an annual-average basis (8.4 mgd from Lake Thunderbird and 4.2 mgd from the existing groundwater wellfield). Table 3-1 summarizes the annual-average yields from each of the City's existing water resource.

TABLE 3-1
Existing Water Resource Capacities

Existing Water Resources	Annual Average Yield (mgd)
Garber-Wellington Aquifer Existing Wellfield Safe Yield (28 Wells)	4.2
Lake Thunderbird Safe Yield Allocation (43.8 percent of Total Safe Yield of 19.2 mgd)	8.4
Total	12.6

Over the next 40 years, the City's water demands are projected to greatly exceed the existing water resources capacity. Based on the planning curves presented in Section 1, Baseline Development, the City's annual-average water resource yield is projected to increase to 41.9 mgd by Year 2040. Total sustainable yield from all secured water resources must meet or exceed this annual supply. Accordingly, this capacity is considered the minimum water resources need for the planning horizon.

This considered, it is recommended that the City of Norman secure additional water resource(s) equivalent to an annual-average water supply of 30 mgd (projected 41.9 mgd less existing capacity of 12.6 mgd). Figure 3-1 illustrates the water resources capacities targeted for the planning horizon.

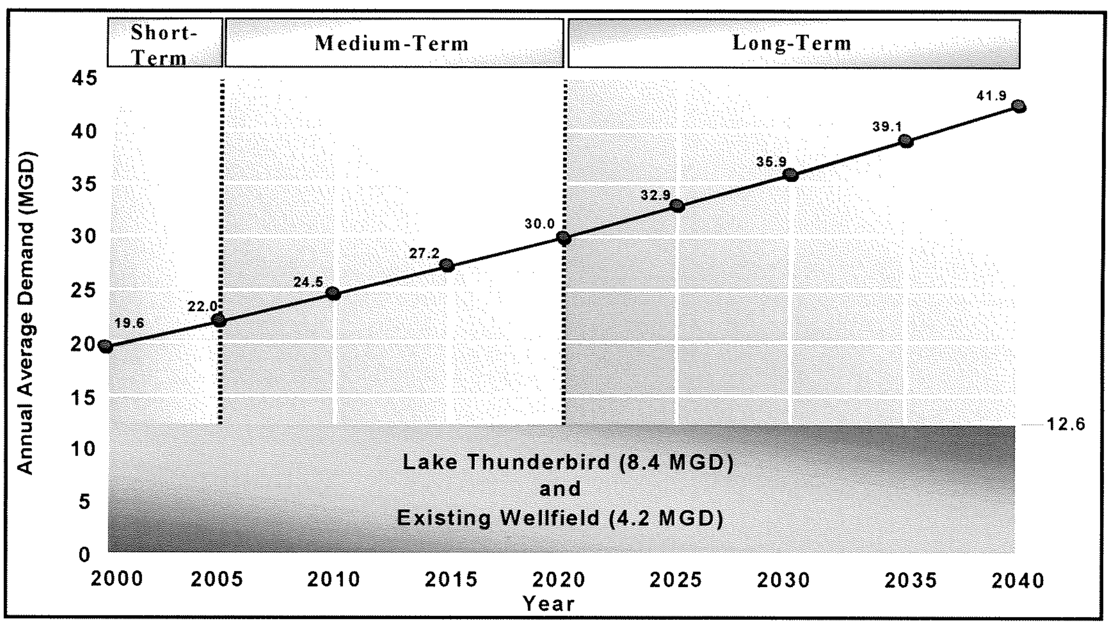


FIGURE 3-1
Planning Capacity: Resources Target

Considering the water demand projections for the planning horizon, the City is faced with the task of securing a safe and plentiful water supply for the future. In addition to expanding the City's existing supply sources, several opportunities are available to the City to develop new supply sources. This section identifies such potentially available opportunities. Additionally, an initial screening of each alternative is presented to bring to light the most favorable supply sources for conceptual development under this water supply plan. Conceptual development of preliminary screened water resource alternatives is presented in Section 3.3.

Necessitated by capacity limitations with the City's existing two water resources, additional water resource alternatives are needed to satisfy the annual-average water demands over the planning horizon. Such packaging of alternatives is typically necessary due to the inability of one resource to satisfy all demands. Additionally, packaging of resources is often necessary due to differing implementation windows. Accordingly, water supply sources highlighted for development are assembled into plans with the focus on satisfying not only the Year 2040 needs, but also the short- and mid-term needs. Associated conveyance and treatment subsystems are presented in Section 3.3.

3.2.2 Expand Existing Water Resources

Additional Garber-Wellington Aquifer Yield

The City of Norman overlies the GWA, which is utilized by several municipalities in Central Oklahoma as a water resource. Production rates have risen throughout the 1990s, bringing to the forefront the potential option of wellfield expansion and discussion on sustainable production. Current operating procedures and a characterization of the aquifer were presented in Section 2. However, a review of some pertinent information is necessary to facilitate discussion on the potential continued development of the aquifer.

The City's existing wellfield, has a current annual-average production rate of about 4.2 mgd. The City currently operates 31 wells, which produce water drawn largely from the confined portion of the aquifer. During periods of high demand, the City's wells are operated as peaking facilities, which produce up to 8.1 mgd over short durations to meet maximum-day demands. For reasons discussed in Section 2, annual-average production at no greater than 4.2 mgd from the existing wellfield should be maintained by the City for the planning horizon.

As also discussed in Section 2, a potential hurdle to the City with respect to wellfield production is the anticipated Arsenic Rule (AR). The 1996 SDWA Amendments required the EPA to propose a new AR by January 2000. The rule, finalized in January 2001, set the arsenic MCL at 10 micrograms per liter (μg/L) (or 10 parts per billion [ppb]). A five-year grace period is in effect; hence, by January 2006, all City of Norman groundwater wells must be in compliance with the new rule. As noted in Section 2, historic water-quality data suggest that as many as 11 of the City's wells do not meet a 10 μg/L MCL. To address this potential regulatory hurdle, it is recommended that the City initiate a groundwater quality management strategy.

The groundwater quality management strategy should be based on monitoring water quality for each well to identify wells producing water with sensitive water quality. For wells producing sensitive water quality supply, utilize a packer sampler to perform a water-quality log based on producing intervals. Using this, intervals within a specific well that produce poor water quality can be closed, allowing the well to continue producing water of adequate quality. In addition, wells that produce water of questionable quality could be reduced to standby status, i.e., reserved for use in meeting peak demands. Although this may reduce production from several wells throughout the year, it should not affect wells to the point that the annual-average production of 4.2 mgd cannot be met. In the event well rehabilitation proves ineffective and lost production capacity is not acceptable, it is recommended that the City include treatment facilities as a contingent option in the groundwater quality management strategy.

Considering the low yield per wellhead production from the City's existing wells, it is very unlikely that individual wellhead treatment will be cost effective. Alternatively, it is recommended that one or more common treatment facilities be considered for compliance with the Arsenic MCL. A likely scenario would include a softening and membrane process system along Highway 77 to collectively remove high arsenic concentrations from wells along that corridor.

Due to the combination of the limited safe yield of the confined aquifer and potential water quality issues, future aquifer development is recommended only for the unconfined portion of the aquifer in the eastern part of the City. The Garber-Wellington Association has identified an area for future development, shown on Figure 3-2, with an estimated freshwater thickness of over 400 feet. Although the Garber-Wellington Association has suggested that a yield of about 20 mgd (requiring 60 new wellheads) is achievable for this area, proper aquifer field testing will reveal a more definitive sustainable yield. Due to the relatively low productivity of the aquifer and the unknown response to large-scale pumping, development of the aquifer should proceed in a methodical, carefully planned direction. It is recommended that the City begin a new wellfield expansion program, consisting of 30 new wells, in the unconfined portion of the aquifer. When completed, it is reasonable at this juncture to assume the wellfield expansion can support a sustainable yield of 10 mgd with peaking supply to 14 mgd. Notably, it is recommended that groundwater produced by the new eastern wellfield be configured to allow common treatment, if required, for current and future SDWA regulations.

Additional Lake Thunderbird Yield

Under-Utilized COMCD Allocations. The total sustainable yield from Lake Thunderbird is 19.2 mgd (21,600 ac-ft per year). Of this total sustainable yield, 8.4 mgd (43.8 percent) is allocated to Norman through contract agreement with the COMCD. The remainder of the yield is allocated between Midwest City and Del City. Specifically, Midwest City is allocated 7.8 mgd (40.4 percent) and Del City is allocated 3.0 mgd (15.8 percent). A review of COMCD pump data for the years 1990 through 1998 indicates that Midwest City and Del City are not currently utilizing their full allocation. Table 3-2 summarizes recent municipal water use and annual surplus from Lake Thunderbird among the three cities.

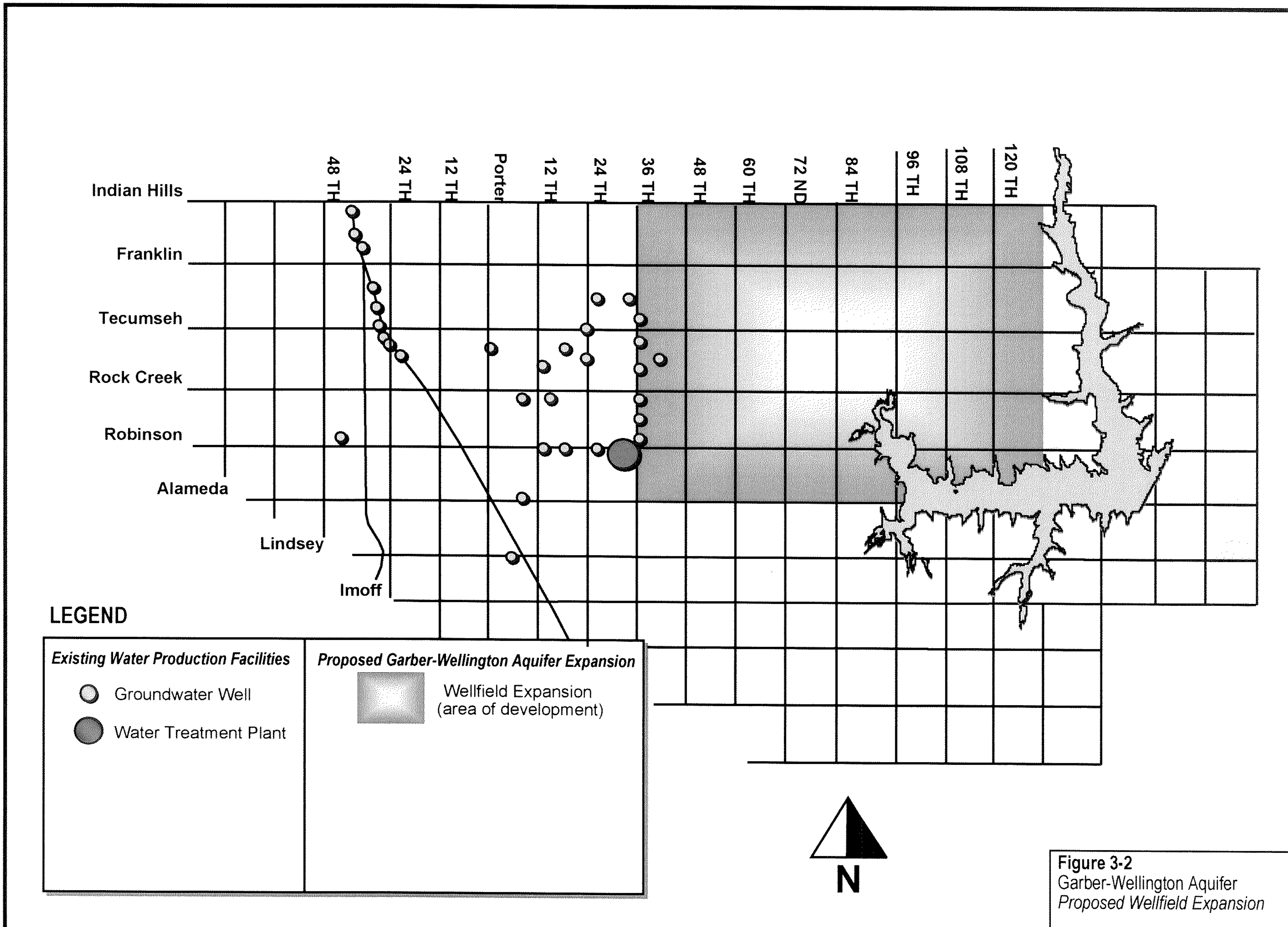


Figure 3-2
Garber-Wellington Aquifer
Proposed Wellfield Expansion

TABLE 3-2
Water Use From Lake Thunderbird

	City of Norman			City of Midwest City			City of Del City		
Year	Allocation (mgd)	Use (mgd)	Surplus (mgd)	Allocation (mgd)	Use (mgd)	Surplus (mgd)	Allocation (mgd)	Use (mgd)	Surplus (mgd)
1990	8.4	8.5	-0.1	7.8	5.8	2.0	3.0	2.3	0.7
1991	8.4	8.4	0	7.8	5.1	2.7	3.0	2.6	0.5
1992	8.4	8.2	0.2	7.8	5.2	2.6	3.0	2.5	0.5
1993	8.4	8.1	0.3	7.8	5.3	2.5	3.0	2.6	0.4
1994	8.4	9.8	-0.8	7.8	5.4	2.4	3.0	2.4	0.6
1995	8.4	8.8	-0.4	7.8	3.9	3.9	3.0	2.5	0.5
1996	8.4	7.3	1.1	7.8	4.2	3.6	3.0	2.6	0.5
1997	8.4	8.0	0.4	7.8	3.7	4.1	3.0	2.1	0.9
1998	8.4	9.5	-1.1	7.8	3.6 [a]	4.2	3.0	1.7 [a]	1.3

Note:
[a] Includes data through September 1998

City of Norman staff has discussed with Midwest City and Del City representatives the possibility of Norman gaining use of these under-utilized allocations. Both cities indicated that Norman could use their surplus supply until either city needs their respective supply. Although both cities agreed that Norman could use their allocation, neither indicated a willingness to sell their water rights or enter into contract for relinquishing the subject supply. Also, neither Midwest City nor Del City indicated a willingness to enter a formalized water use agreement. This potential supply of 3 to 5 mgd is available to Norman, at least as a short-term supply. However, the reliability of the additional supply for any given year is highly uncertain.

Water demands for Norman, Midwest City, and Del City will fluctuate for any given year. One key factor in such water demand fluctuation is weather patterns. Due to the inherent inaccuracies in predicting weather patterns and water demands for all three cities for any given year, it would be difficult to ascertain the additional water supply available to Norman. Furthermore, the additional water supply available to the City in the future would decrease as Midwest City and/or Del City's overall water demand increases due to population growth, per capita usage increase, and/or commercial/industrial development.

As presented in Section 2, existing raw water conveyance system capacity is limited to approximately 14 mgd. As such, an upgrade and/or expansion of the existing raw water conveyance system would be required for Norman to realize the benefits of the under-utilized 3 to 5 mgd yield from Lake Thunderbird. Because the supply quantity and duration available to Norman from Midwest City and Del City's under-utilized allocations are indefinite, development of additional conveyance and/or storage infrastructure would be difficult to quantify or justify. However, if additional conveyance and/or infrastructure necessary for development of another raw water source, say Southeast Oklahoma surface water supplies, affords the opportunity, by all means the City of Norman should consider the under-utilized Lake Thunderbird allocations as water for the taking. As such, obtaining surplus supply from Midwest City and Del City under-utilized Lake Thunderbird allocations is considered a supplemental resource, when available, for this water supply plan.

Flood Control Pool. As detailed in Section 2, the City of Norman utilizes water from Lake Thunderbird via a contracted allocation from the COMCD. The City is allocated 8.4 mgd on an annual-average basis, with the remaining portion of the available 19.2 mgd divided between Midwest City and Del City. Although a re-allocation of the available water supply is unlikely, the City may be able to increase the total amount of water taken from Lake Thunderbird, as stated in the current contract between the COMCD and the City.

Discharge from Lake Thunderbird flows over the Norman Dam to the Little River where downstream water rights are nearly negligible (40 ac-ft/year, or 0.036 mgd). Figure 3-3 presents streamflow data from 1990 to 1998 taken from the USGS gauging station No. 07230000, located on the Little River just below Norman Dam. As shown, the baseflow in the Little River appears fairly consistent approaching 1.0 mgd, with releases from Lake Thunderbird causing dramatic increases in flow. Based on the small downstream water demands that can likely be satisfied by baseflow in the Little River, water released from Lake Thunderbird presents a potential water resource for the City. Essentially, this water is lost to the river, and not needed for any downstream water rights.

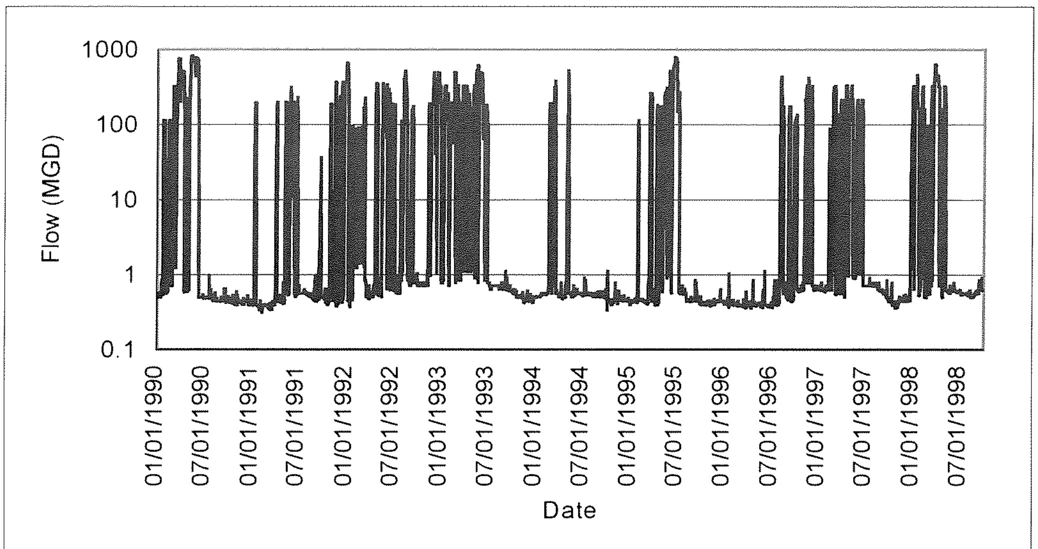


FIGURE 3-3
Little River Flow Below Lake Thunderbird

If discharge from the lake occurs from the flood pool rather than the conservation pool (water level above elevation 1039.0 ft), water withdrawn by the City at that time would not count against their allocation of 8.4 mgd. This water is classified as "additional water" under the City's current contract with the COMCD. More specifically, any water utilized by the City on a day that water is released to the Little River would essentially be "free water" and not counted as part of the City's annual allotment. After a review of pertinent data, it is evident that the City would not gain significant yield in addition to their allocation. Data was reviewed on a daily time step from January 1, 1990, through September 30, 1998, (the period of record for Lake Thunderbird releases shown on Figure 3-3). Table 3-3 presents a summary of the amount of water that would have been gained for the years 1990 through 1998.

TABLE 3-3
Potential Additional Water From Lake Thunderbird, 1990-1998

Year	Annual Average Usage (mgd)	Total Additional Water Gained	
		MG/Year	mgd
1990	8.5	813	2.2
1991	8.4	645	1.8
1992	8.2	1,494	4.1
1993	8.1	1,038	2.8
1994	9.2	240	0.7
1995	8.8	870	2.4
1996	7.3	477	1.3
1997	8.0	729	2.0
1998	9.5	540	1.5
Average			**2.1**

As shown, the largest quantity of water potentially gained for any year of record would have been 4.1 mgd (1992). Considering the average of 2.1 mgd for the historical record, this would equate to annual production from approximately six Garber-Wellington wells. Based on this analysis, it does not appear that this scenario would provide much help to the City with short-term additional water resources needs. Used in combination with other Lake Thunderbird options, this alternate will be considered as a conditional water resources alternative for this Strategic Water Supply Plan.

Another potential Lake Thunderbird alternative may provide an exceptional supply to the City. The excess water that is currently released from Lake Thunderbird may be captured by the City and stored for future use. The total volume of water that is released, after subtracting out about 1.0 mgd for Little River baseflow, could help the City meet demands over the planning horizon. This total volume of water released from 1990 to 1998 (potential supply) is presented in Table 3-4.

TABLE 3-4
Water Released from Lake Thunderbird, 1990-1998

Year	Total Water Released	
	MG/Year	mgd
1990	42,372	116.1
1991	16,048	44.0
1992	36,614	100.3
1993	33,733	92.4
1994	5,993	16.4
1995	25,544	70.0
1996	10,668	29.2
1997	15,160	41.5
1998	21,201	77.7

As shown, for every year except 1994 and 1996, the City could have captured over 30 mgd, the required quantity over the planning horizon. However, this would require construction of a terminal reservoir to provide storage of this flow.

Recommendation. The reliability issues that exist in capturing water from Lake Thunderbird's flood pool provide too much uncertainty for consideration as an exclusive water resource alternative. The first option described, simply not counting the City's withdrawal during periods of release from the flood pool, could provide significant short-term benefit to the City as a conditional water resource alternative. The second option, however, would likely provide a greater water resource in most years, but as shown in 1994, dry years would not provide the City with a reliable water resource. In addition, construction and operation of a terminal reservoir would be required. This concept is considered further in following sections as part of other potential Lake Thunderbird augmentation options.

3.2.3 New Groundwater Resources

Three potential groundwater resources, in addition to the GWA, were evaluated as possible alternatives to provide safe, reliable water supply to the City of Norman for the planning horizon.

- Arbuckle Simpson Aquifer
- Canadian Terrace Deposits
- Canadian Alluvial Deposits

Arbuckle Simpson Aquifer

The Arbuckle-Simpson Aquifer underlies an area in excess of 500-square-miles in South-Central Oklahoma, some 65 miles south of Norman. The outcrop area of the aquifer lies within Murray, Pontotoc, Carter, and Johnston Counties. Based on characterization of the aquifer by the Oklahoma Geological Survey (*Hydrology of the Arbuckle Mountains Area, South-Central Oklahoma, Circular 91, Fairchild, et al., 1990)*, the aquifer consists of limestone, dolomite (carbonate rock), and sandstone formations. The aquifer has been intensely faulted, with numerous major faults and associated minor faults, fractures, and joints. Additionally, the aquifer is characterized as a karst aquifer, as the carbonate rock is soluble in the slightly acidic water. Infiltrating water slowly dissolves soluble carbonate rock, which forms conduit-like openings and enlarges the faults and fractures. This results in an irregular network of openings extending both vertically and horizontally. As such, groundwater flow in the aquifer is strongly controlled by aquifer structure as well as aquifer lithology. Numerous springs in the outcrop area of the aquifer indicates the strong influence of aquifer structural control on groundwater flow. General lithology of the Arbuckle-Simpson aquifer is presented in Table 3-5.

Based on the Oklahoma Geological Survey Circular 91, the volume of water in the 500-square-mile outcrop area has been estimated at approximately 9 million ac-ft. Natural recharge to the aquifer over the outcrop area has been estimated at approximately 128,000 ac-ft per year (approximately 114 mgd). Discharge from the aquifer is by evapotranspiration, baseflow in springs and streams, and by pumpage from a few existing wells. Monitoring data of water levels in the aquifer and baseflow in streams located in the outcrop area indicates that there is a close hydraulic connection between the aquifer and surface water in the outcrop area. Hydraulic connection between surface water and the aquifer is also supported by similar water quality in groundwater and surface water.

Although there are production wells in the Arbuckle-Simpson Aquifer, the aquifer can largely be considered as undeveloped with respect to municipal water supply. As such, several issues and aquifer data would be required to consider development of this alternative as a water supply source for the City of Norman. To support a municipal wellfield, contiguous land overlaying the aquifer would need to be identified for purchase of necessary water rights as a wellfield infrastructure site location. Alternately, water rights could potentially be purchased or leased from landowner(s), contingent on the landowners willingness to pursue such a venture and acceptable purchase or lease agreements between the City and the landowners. Additionally, geologic and hydrogeologic factors of the aquifer would have to be ascertained specific to the wellfield area. This data would be critical in developing a properly designed and operated wellfield to maintain long-term production and water quality. Based on reported well production in Oklahoma Geological Survey Circular 91, individual well production ranges from less than 100 gpm to greater than 2,000 gpm. For example, based on reported production of wells in Pontotoc County, one well produces approximately 37 gpm while another well produces approximately 2,500 gpm. In short, well production is highly dependent on the well penetrating fractures and karsts within the aquifer and the degree of interconnection of such fractures and karsts. Because the aquifer is a karst aquifer, it would be sensitive to influence by surface water and potential contamination. If water produced from the wellfield was under the direct

Table 3-5

Generalized Lithologic Description and Water-Yielding Characteristics of Strata in the Arbuckle-Simpson Aquifer

System	Series	Stratigraphic Unit			Thickness (ft)	Lithologic Description	Water-Well Yields
Quaternary	Holocene	Alluvium			0-85	Gravel, sand, silt, clay	10-100 gal/min
Cretaceous	Lower	Cretaceous rocks undifferentiated			200-700	White to yellow, medium-grained weakly indurated sand with varicolored clay	1-50 gal/min
	Lower Permian to Middle Ordovician	Paleozoic rocks undifferentiated			0-5,000 (est)	Shale, siltstone, sandstone, or other rock types	1-65 gal/min
Ordovician	Middle	Simpson Group	Bromide Formation Tulip Creek Formation McLish Formation Oil Creek Formation Joins Formation	Arbuckle Simpson Aquifer	1,000-2,300	Upper part: buff limestone; grayish-green shale; brown to white, fine-to medium-grained sandstone Lower part: gray to tan, granular limestone with greenish-gray shale and brown, fine- to medium-grained sandstone	Commonly 100-200 gal/min; reportedly as much as 400 gal/min
Ordovician / Cambrian	Lower / Upper	Arbuckle Group	West Spring Creek Formation Kindblade Formation Cool Creek Formation McKenzie Hill Formation Butterly Dolomite Signal Mountain Formation Royer Dolomite Fort Sill Limestone	Arbuckle Simpson Aquifer	4,000-6,700	Principally limestone in the west and dolomite in the east, with a few thin beds of sandstone that thicken to the east Fine-grained limestone passing eastward into tan to pink, fine- to coarse grained dolomite	Commonly 200-500 gal/min; some wells 800-1,000 ft deep produce as much as 2,500 gal/min
Cambrian	Upper	Timbered Hills Group	Honey Creek Limestone Reagan Sandstone		175-675	Very glauconitic and silty, gray to greenish-brown, fine to coarsely crystalline limestone and brown, coarse-grained sandstone	Limited
Cambrian	Middle	Colbert Porphyry			Drilled thickness, 4,500	Red-brown rhyolite porphyry	Limited
Precambrian		Tishomingo Granite, Troy Granite			[est. thickness 10mi]	Pink, coarse-grained granite	Limited

OKC\table 3-5.xls

influence of surface water, it would require treatment as such. Treatment would include filtration and disinfection, at a minimum, prior to distribution.

Development of the Arbuckle-Simpson Aquifer as a water supply source would require implementation of a wellfield and associated field piping network, water collection/storage facilities, and conveyance system to transfer water from the wellfield to Norman. Depending on water quality, treatment facilities may also be warranted to treat the water to drinking water standards prior to distribution. However, the suitability and feasibility of developing this alternative as a water supply source is dependent on further investigation to identify available water rights, aquifer hydrologic and hydrogeologic properties, sustainable yield, aquifer performance parameters, and water quality. A recent attempt by the City of Norman to initiate an investigative process to determine the viability of the Arbuckle Simpson Aquifer as a future water resource was resoundly thwarted by the citizens. As such, this alternative is discounted under this Strategic Water Supply Plan.

Canadian Terrace Deposits

Based on Oklahoma Geological Survey information (*Ground-Water Resources: Cleveland and Oklahoma Counties, Circular 71, Woods and Burton, 1968*), the Canadian Terrace deposits near Norman have an average saturated thickness of 40 feet. Groundwater occurs at depths generally less than 50 feet below surface. Recharge to the deposits is mainly from infiltration of precipitation. Additionally, it has been estimated that favorable sites in the deposits could potentially support individual well production upwards of 200 gpm. However, such locations are apparently limited. Previous water supply studies estimated that the deposits would be limited to supporting low producing wells. Reported production from individual irrigation and domestic wells developed in the Canadian Terrace deposits suggests that individual well production is limited to approximately 100 gpm.

Little data is available on overall sustainable yield and water quality from the Canadian Terrace deposits. Based on previous studies, sustainable yield of a potential wellfield is low. Additionally, sustainable yield would also need to account for existing privately owned wells withdrawing water from the deposits. Furthermore, this groundwater supply could likely be considered sensitive to surface water and potential contamination. As such, it is likely that this water would require treatment as surface water at a minimum. With these issues in mind, the Canadian Terrace deposits are discounted for the planning horizon under the Strategic Water Supply Plan.

Canadian Alluvial Deposits

The channels and floodplain of the Canadian River Valley are covered with alluvium, which consists of lenticular beds of sand, silt, and clay. This alluvium forms a relatively shallow, unconfined aquifer. As previously mentioned, development of the Canadian Alluvial deposits as a water supply source for Norman has been considered in previous water supply studies. The area that received the most interest is commonly referred to as "Ten Mile Flat." Based on characterization reported in Oklahoma Geological Survey Circular 71, the alluvium thickness in the Ten Mile Flat ranges from 20 to 40 feet. However, in certain locations the maximum thickness of the alluvium ranges from 60 to 70 feet. Additionally, the alluvium is approximately 3 miles wide in the Ten Mile Flat area. Groundwater levels are near the ground surface in some areas. In other areas, groundwater has been reported at approximately 10 feet below ground surface.

Recharge to the alluvial deposits has been estimated between 1,500 to 6,400 ac-ft per year in previous studies. Recharge to the alluvium deposits is through infiltration of precipitation, infiltration of surface water runoff from surrounding areas, and groundwater flowing parallel with the river. Discharge from the alluvium is from evapotranspiration and groundwater flow out of the area. Additionally, the alluvium deposits are hydraulically connected to the South Canadian River. There is an exchange of water from the Canadian River and the alluvial aquifer, depending on river stage and water level in the aquifer.

Individual well production potential was estimated at 300 to 400 gpm in the *Groundwater Development Plan (1982)*. However, Oklahoma Geological Survey Circular 71 reports wells developed in the alluvial produce from less than 100 gpm to as much as 300 gpm. Reported water quality indicates elevated chloride, nitrate, and TDS concentrations in some areas (*Groundwater Development Plan, 1982)*. Additionally, the Oklahoma Geological Survey Circular 71 reports potential chemical and bacteriological water quality issues in some areas; although, both studies report that water quality varies widely. Anecdotal data reported by City staff suggest high TDS and dissolved metal concentrations were observed for a recent test well in the Ten Mile Flat area. This considered, development of this resource would require implementation of treatment facilities prior to distribution.

For development of the alluvial aquifer as a water supply source, the sustainable yield from a potential wellfield would be dependent on recharge, subsurface groundwater flow (both into and out of the area), and production from privately owned wells in the area. Based on these factors, the potential yield from a wellfield developed in the alluvial aquifer has been estimated at approximately 1 to 3 mgd. However, little production data is available to support development of such a wellfield. A comprehensive hydrologic and hydrogeologic evaluation of the aquifer is recommended prior to implementing this alternative. Key issues to ascertain before implementation include long-term production capacity (sustainable yield) in light of effects on subsurface flow out of the area (including base flow in the river), influence on production of existing wells, and degree of infiltration from the river associated with pumping from the aquifer. Additionally, it is recommended that aquifer testing be performed to develop proper well spacing, development, and capacity criteria. Furthermore, such studies should evaluate the potential of augmenting aquifer sustainable yield through a potential aquifer storage and recovery program (ASR). An ASR program could potentially be developed by diverting flow from the Canadian River to infiltration basins constructed over the Ten Mile Flat area.

In addition to data specific to production capacity associated with a potential wellfield in the alluvial aquifer, additional water quality testing would be necessary. Considering that water quality varies widely, it would be prudent to identify the associated treatment requirements prior to development. As discussed, the alluvial aquifer is an unconfined aquifer with a relatively shallow water table that is, to some degree, hydraulically connected to the Canadian River. As such, the alluvial aquifer is considered a sensitive aquifer under the direct influence of surface water. In such a case, water produced from the alluvial aquifer would require treatment as a surface water. One possible treatment scenario would be to pump water from the wellfield to a new terminal reservoir or Lake Thunderbird for subsequent treatment at the WTP. Although, water quality issues could necessitate a new

Westside WTP with an advanced treatment process train (such as membranes) to provide effective barriers for removing elevated chlorides, nitrates, and TDS prior to distribution.

This alternative could be developed in stages to augment other supply sources in meeting the City's water consumption demands. However, such development is contingent on further investigation to confirm the suitability of developing the Canadian Alluvial deposits as a water supply source. Due to the apparent negligible yield potential and suspect water quality, this alternative is discounted from further consideration for the purposes of this Strategic Water Supply Plan.

3.2.4 New Surface Water Resources

Considering the limitations of the City's existing water resources and realizing that no readily available new groundwater resource can provide the needed supply for the planning horizon, it is evident that the City must rely on additional surface water resources to meet future needs. When considering a potential surface water supply for development, a primary concern is water quality. Surface water quality is generally a function of the watershed. The mountainous terrain of Southeast Oklahoma contains a multitude of rapidly draining and undeveloped watersheds. This part of Oklahoma can be characterized as largely rural with watersheds unaffected by large metropolitan areas. Furthermore, Southeast Oklahoma represents some of the most prolific watersheds in the State. More than half of OKC's current total water rights are to water bodies in Southeast Oklahoma. Notably, OKC is currently pursuing the development of additional water rights in this area. With the acquisition of remote water resources comes the need for conveyance infrastructure. Since Norman lies geographically between OKC and Southeast Oklahoma, the City of Norman has the unique ability to partner with Oklahoma City in the development of existing and planned Southeast Oklahoma resources. This phenomenon translates into an "economies of scale." For these reasons, this Strategic Water Supply Plan has largely focused on identification and analysis of possible additional surface water resources in Southeast Oklahoma.

McGee Creek Reservoir

McGee Creek Reservoir is a multipurpose reservoir located in Southeast Oklahoma (Atoka County). The reservoir was constructed during the 1980s. Reservoir operation was turned over to the McGee Creek Authority in 1990. Information provided by the U.S. Bureau of Reclamation indicates McGee Creek provides 103,000 ac-ft of conservation storage and 86,000 ac-ft of flood control storage. The conservation storage pool yields 71,800 ac-ft per year (64 mgd) for water supply. McGee Creek provides water supply to the Cities of Oklahoma City and Atoka, County of Atoka, and the Southern Oklahoma Development Trust.

The Bureau of Reclamation reports total cost of the McGee Creek project was $169.7 million. Of this total, $111.4 million was appropriated to conservation and inactive reservoir storage. The project was paid out in 1992 at a reduced cost of $86 million by the McGee Creek Authority (headed by Oklahoma City Water Utilities Trust [OCWUT]) through issuance of revenue bonds.

According to the Oklahoma Water Resources Board (OWRB), permits to McGee Creek water supply total 60,000 ac-ft per year (53.6 mgd); of which; 40,000 ac-ft per year (35.7 mgd) are permitted to OKC. Considering water supply permits on file with OWRB, 11,800 ac-ft per year (10.5 mgd) of water supply from McGee Creek is unallocated and available. The potential also exists to obtain additional water supply from the McGee Creek Authority, contingent on their willingness to sell such water rights. To secure water supply from McGee Creek, it is likely the City of Norman would purchase conservation storage capacity from the McGee Creek Authority. To this end, the City of Norman would be required to reimburse the OCWUT for past payments on debt service and lake operation and maintenance (O&M) as well as assume remaining debt service and future O&M costs. Cost data pertinent to McGee Creek was obtained from OKC and are summarized in Table 3-6.

TABLE 3-6
McGee Creek
Cost Data

Item	Cost [a] (x $1,000)
Previous Payments [b]	61,148
Future Payment [c]	79,811
Total Cost	**140,959**
Estimated Annual Yield	71,800 ac-ft
Total Unit Cost	**$1,963/ac-ft/yr**

Notes:
[a] Present value of the total debt if paid in full (one time payment).
[b] Present value of cost paid since bond issue in 1992, as reported by OCWUT. Includes debt based on bond yield rate and incurred lake O&M cost.
[c] Present value of debt for the remaining 23 years bond life.

Assuming available capacity in McGee Creek is limited to unallocated water supply rights, the cost for securing 11,800 ac-ft per year (10.5 mgd) water supply from McGee Creek to augment other supply sources would be approximately $23 million. In addition to costs associated with securing water supply, costs for conveyance infrastructure and treatment facilities would be incurred for full development of this potential water supply alternative.

OKC currently has a conveyance system that transfers water supply from Southeast Oklahoma to Lake Stanley Draper. Water supply from McGee Creek Reservoir is transferred via the McGee Creek pump station to the Atoka Reservoir. Raw water supply from Atoka Reservoir is transferred to Lake Draper, some 100 miles and 600 feet upgradient, via six pump stations. The Atoka pipeline intersects Lake Thunderbird at Hog Creek. If a mutually acceptable agreement could be negotiated, the City of Norman could potentially purchase capacity on the Atoka/McGee Creek conveyance system, thereby developing a partnership in owning and operating the conveyance infrastructure. Although a less attractive alternative for Norman, the City could potentially lease capacity on the conveyance system from OKC. For both scenarios, water supply could be diverted from the conveyance pipeline to Hog Creek and hence Lake Thunderbird. New or modified conveyance infrastructure at Lake Thunderbird would transfer water to the WTP. Additional treatment capacity at the WTP would be required for the additional supply.

With City of Norman and Oklahoma City input, the possibility of purchasing water supply storage and yield in McGee Creek and associated conveyance scenarios was discussed. Although OKC indicated this could potentially be an option for Norman, discussions also indicated that political and public issues would prevent development. In short, OKC staff indicated that, at least from their viewpoint, a more likely scenario would be development of a wholesale purchase agreement for either treated or raw water on a unit cost basis. Considering the high relative cost to secure water rights and OCWUT's apparent unwillingness to sell, this alternative is discounted from further development under the Strategic Water Supply Plan. Alternatives for wholesale purchase of treated or raw water from OKC are considered subsequently.

Sardis Reservoir

Sardis Reservoir is one of two major reservoirs located in the Kiamichi River Basin in Southeast Oklahoma. The U.S. Army Corps of Engineers (COE) constructed Sardis in 1983. Authorization for impoundment was for a multi-purpose reservoir serving flood control, water supply, recreation, and fish and wildlife management. Based on initial storage capacity, Sardis Reservoir provides 396,900 ac-ft of storage capacity. This storage capacity is allocated to flood control, conservation, and inactive storage. Table 3-7 summarizes the water storage allocations.

TABLE 3-7
Sardis Reservoir Storage Allocation

Initial Storage Allocation	Elevation (ft)	Storage Capacity (ac-ft)
Flood Control	599 – 607	122,570
Conservation[a]	542 – 599	274,210
Inactive	530 – 542	120
Total	**530 – 607**	**396,900**

Note:
[a] Conservation Storage Yield = 140 mgd

As indicated, the total conservation storage capacity is 274,210 ac-ft. Based on estimates provided by the COE and OWRB, this conservation storage yields approximately 156,800 ac-ft per year (140 mgd) of water supply. Currently, 7,038 ac-ft per year (6.3 mgd) of this total yield is allocated through four permits on file with OWRB. This considered, there are 149,762 ac-ft per year (134 mgd) of water available for appropriation. However, OWRB reports there are five permits currently pending for water conservation pool yield. These pending permits total to 486,424 ac-ft per year (434 mgd), more than three times the dependable yield from the reservoir.

The State of Oklahoma entered into contract with the COE for construction of Sardis Reservoir. Based on this contract, the total project cost for constructing Sardis was appropriated to the various storage allocations. Accordingly, the State is responsible for debt service attributed to conservation storage. Additionally, total water conservation storage costs were further appropriated based on "Present Use" and "Future Use" allocation of the conservation storage capacity. Essentially, Present and Future Use allocation is a means for the project stakeholders to divide debt service based on projected actual water supply needs, which is not uncommon in COE construction contracts. For Sardis, 47 percent of the total conservation storage (and cost) was allocated to Present Use. The remaining 53 percent was allocated to Future Use. Under the contract, the Future Use debt accumulates interest at approximately 4 percent annually until the storage capacity is utilized.

Based on initial (1974) construction estimates for Sardis, water conservation storage costs totaled $16.4 million. Several legal issues surround the legitimacy of the State of Oklahoma contracting debt on Sardis. As such, the State has, in part, deferred payment. The outstanding storage costs are currently reported by OWRB at approximately $40 million. OWRB also estimates that total annual debt service for Current and Future Use water supply would likely be $2 million.

As previously mentioned, there are several issues surrounding the State of Oklahoma contracting debt service on Sardis. In fact, Sardis is the only lake in Oklahoma for which the State holds a contract to repay conservation storage costs. In addition to these issues, several entities have unresolved issues regarding Sardis. To address such issues, the State Legislature passed House Concurrent Resolution (HCR) 1066. HCR 1066 directed the Kiamichi River Basin Working Group (comprised of OWRB, Tribal advisors, and local citizens) to submit a plan proposal to the State Legislature in February 2000 that retires the debt on Sardis Reservoir and distributes the water rights. An additional component of HCR 1066 includes lake level management plans for Sardis and Hugo Reservoirs. Recent events surrounding the Kiamichi River Basin required extension of the submission schedule pending the mutual resolution of outstanding issues by members of the Kiamichi River Basin Working Group.

Under HCR 1066, OWRB, COE, and the Office of Management and Budget are negotiating details to potentially discount the outstanding debt on Sardis. Additionally, an independent accounting firm is evaluating the details of a potential discounted prepayment to the COE for Sardis. With such activities in progress, OWRB has indicated that the debt on Sardis may be discounted from $40 to $20 million, or less. However, terms for retiring the outstanding debt have not been finalized. Additionally, details for purchasing water storage and supply in Sardis have not been finalized, pending the outcome of HCR 1066 and resulting State legislation.

A key component of HCR 1066 is developing the Kiamichi River Basin to satisfy the needs of local communities in the area. To meet this end, the Kiamichi River Basin Working Group has highlighted 10 "Cornerstone Principles" for developing the Kiamichi River Basin. Regarding Sardis and the Cornerstone Principles, 20,000 ac-ft per year (approximately 18 mgd) of water supply have been set aside for local communities. Additionally, a Sardis Lake Level Management Plan has been proposed. Under this plan, drawdown, and hence water supply withdrawal, of Sardis Reservoir would be limited to the fall and winter months (September through February). As proposed, lake level drawdown is limited to 4 feet or less during these months.

In addition to the Kiamichi River Basin Working Group, several other entities and municipalities have shown an interest in developing Sardis Reservoir for water supply. Based on an interim report by OWRB, there have been eight different proposals for securing water supply from Sardis Reservoir. Sardis Lake Water Authority, Clayton Chamber of Commerce, Sardis Water Resources, City of Oklahoma City, Central Oklahoma Water Authority, Association of Central Oklahoma Governments (ACOG), and entities in Texas have submitted such proposals for securing water from Sardis.

In summary, the total water supply yield from Sardis Reservoir is 156,800 ac-ft per year. Of this total yield, 20,000 ac-ft per year is set aside for local communities (under HCR 1066). As such, 136,800 ac-ft per year (122 mgd) of water supply is potentially available for other entities or municipalities. On an annual basis, the availability of this water supply will likely be limited to winter and fall months. Based on proposals from OWRB, the cost to secure this water supply would be approximately $40 million, with monies allocated to retire the discounted construction debt with the COE and to funding local communities needs. Ultimately, the availability of water supply directly from Sardis is limited to the outcome of HCR 1066 and any resulting State legislation pertinent to the Kiamichi River Basin. Although OWRB has indicated that a plan to develop Sardis is ongoing for the short-term, actual development of water supply is likely limited to the long-term (approximately 20 years or more).

Considering the potential development by Norman to satisfy the City's long-term water supply needs, development would include infrastructure to convey water supply from Sardis to the City of Norman. Conveyance infrastructure capacity would likely be based on obtaining water supply from September through February under the Sardis Lake Level Management Plan. Under this scenario, the City would be required to implement infrastructure with the capacity to convey approximately 60 mgd on average from Sardis to a terminal reservoir during these months. With terminal storage, the City could match water supply with actual water demands over the course of a year. In other words, terminal storage in Norman would allow the City to fully realize an annual-average supply of 30 mgd.

With other Central Oklahoma municipalities' interest in Sardis, the potential exists for Norman to become a partner in developing Sardis. In fact, the City of Norman has expressed interest to OCWUT in the development of Sardis as a water resource for Central Oklahoma if such an arrangement were to materialize. With partnership, other municipalities could share in the cost of securing the water supply, reservoir O&M, and associated infrastructure to convey water from Sardis to Norman or other Central Oklahoma locations. As indicated, nearly all components (including water supply availability, capacity, and cost) surrounding development of Sardis as a water supply source are currently under negotiation with the COE, the State of Oklahoma, and the Sardis Working Group. Although preliminary, likely results from this negotiation would limit obtaining water directly from Sardis. A likely alternative will be utilizing releases from Sardis to support potential water supply development on the Kiamichi River. Therefore, Sardis Reservoir is discounted from further development as a potential water supply alternative under this strategic plan. However, it is recommended the City keep abreast of Sardis, HCR 1066, and any resulting State legislation, as finalization of the Kiamichi River Basin Development Plan may warrant additional consideration for development in the future.

Kiamichi River

The Kiamichi River originates in the Ouachita Mountains of Western Arkansas prior to entering Oklahoma. In Oklahoma, the river flows some 172 miles, crossing through six Oklahoma counties, prior to termination in the Red River. The river is located in the Kiamichi River Basin. With a drainage area of over 1,800-square-miles and an average-annual runoff ranging from 750 to 1,050 ac-ft per square mile, this basin is one of the most prolific watersheds in Oklahoma. Based on information from OWRB and USGS stream gauges, the average-annual flow in the Kiamichi River ranges from 62,300 ac-ft per year (55 mgd) in the northeast to 1,573,000 ac-ft per year (over 1,000 mgd) in the south.

The Kiamichi River is being evaluated under the Kiamichi River Basin Development Plan (HCR 1066). Specifically, the proposed lake level management plans for Sardis (discussed previously) and Hugo (discussed in the following section) will impact seasonal stream flows in the Kiamichi River. Discussion with OWRB indicate approximately 145,600 ac-ft per year (130 mgd) of water supply is potentially available for transfer from the Kiamichi River. As a part of evaluating the Kiamichi River Development Plan, the COE conducted a hydrologic investigation to ascertain the reliability of diverting 130 mgd from the Kiamichi River at Antlers, Oklahoma, in light of the proposed lake level management plans. This study indicates that 130 mgd would be available for diversion approximately 80 percent of the time during the months of February through May. However, the availability of this quantity of water decreases to 10 to 20 percent of the time, on average, during July and August. Figure 3-4 summarizes the estimated reliability of water supply flow in the Kiamichi River.

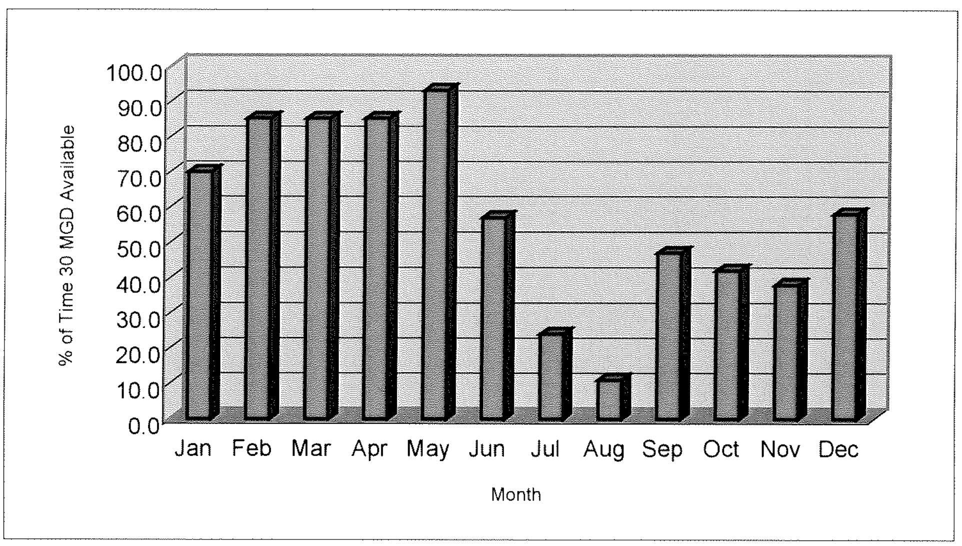


FIGURE 3-4
Availability of Water Supply at Antlers
Above Residual River Flow

The COE study focused on withdrawing water near Antlers, Oklahoma, because this location was considered the most advantageous for diverting flow to McGee Creek Reservoir and hence the City of Oklahoma City's existing Atoka/McGee Creek raw water conveyance system. Another potential location for diverting flow would be at Moyer's Crossing, which is less distant from McGee Creek Reservoir than Antlers. However, an endangered species, the Ouachita Rock Pocketbook Mussel, thrives in the river environment surrounding Moyer's Crossing and is dependent on river flows. Diverting river flow from this area could potentially result in negative environmental impacts to this species of mussel. As such, diverting flow from Moyer's Crossing is discounted.

Unlike a reservoir, the Kiamichi River does not provide water storage. As such, there is no direct cost for securing water rights from the river aside from applicable permit fees. As with any distant surface water supply source, there is a cost associated with developing conveyance and treatment infrastructure. Because the Kiamichi River does not provide water storage, conveyance infrastructure would include an intake structure, conveyance pipeline, pumping system, and a terminal storage reservoir in Norman. As indicated by the COE study, the availability of stream flow for diversion is limited. When water is available for diversion, water supply could be conveyed to a terminal reservoir with storage capacity to balance stream flow with the City's actual water demands. In short, additional conveyance system capacity and terminal storage would be required to balance the availability of water supply and lack of storage in the Kiamichi River.

Raw water could be withdrawn from the Kiamichi River and routed through the McGee Creek and Atoka Reservoirs to the Central Oklahoma area. This conveyance alternative would be contingent on negotiating a mutually acceptable lease rate for the City of Norman to utilize the City of Oklahoma City Atoka/McGee Creek conveyance system. Alternatively, the potential may exist for the City of Norman to partnership in the Atoka/McGee Creek conveyance system through sharing in capital and O&M costs of future upgrades to the system. If such lease or partnership alternatives cannot be negotiated, the City of Norman would need to implement a new conveyance system. In any event, development of a water supply from the Kiamichi River would require a new conveyance system from the Kiamichi River to McGee Creek Reservoir, as there is no existing infrastructure between these two water sources.

As stated in Section 3.2.4, water withdrawal from the Kiamichi River would likely be restricted to a period of four months, when adequate river flow is more reliably present. The combination of a restricted withdrawal time and the volume of water needed (30 mgd annual average) lead to extreme infrastructure needs. Essentially, the City must withdraw an average supply of 90 mgd during the four-month withdrawal period to equal an annual-average supply of 30 mgd. Any available capacity in the existing Atoka/McGee pipeline would pale in comparison to the needed capacity. As such, a new conveyance pipeline would be required.

A pipeline with the capacity to pump an average of 90 mgd over 4 months will be very costly. More specifically, the required pipeline would be a 60-inch-diameter pipeline from the withdrawal point at Antlers to the City of Norman, some 120 miles away. Table 3-8 summarizes the cost estimates for this conveyance system, including pipe and pumping costs. Permit and right-of-way fees are not included.

TABLE 3-8
Preliminary Conveyance System Capital Cost Opinion
Kiamichi River

Component	Cost (x $1,000)
Piping – 60 inch diameter, 120 miles	152,064
Pump Stations	55,000
Total	**207,064**

Notes:
Costs for right-of-ways and easements not included.
Assumes similar features as the existing Atoka/McGee pipeline (7 pump stations, 5 MG holding tank at each pump station, etc.)

In addition to costly pipeline and pump station requirements, a terminal reservoir would be required because storage is not available in the Kiamichi River. These support infrastructure costs do not yet include water treatment, but already greatly exceed $200 million. In addition, annual O&M costs would contribute to high costs. Due to this extremely high capital cost, unreliable flow, and no storage, the Kiamichi River is not further considered as an option for the Strategic Water Supply Plan. Nevertheless, securing water supply from the Kiamichi River could be a potential long-term water supply alternative for Norman. As HCR 1006 unfolds and the Kiamichi River Basin Development Plan takes shape, this option could become attractive as a regional solution.

Hugo Reservoir

Hugo Reservoir, which was constructed in the 1970s, is the impoundment lake of the Kiamichi River in the far southern reach of the Kiamichi River Basin, approximately 18 river miles upstream of the confluence with the Red River. Similar to Sardis, authorization for impounding Hugo was for flood control, water supply, water quality, recreation, and fish and wildlife uses. Conservation storage capacity of Hugo Reservoir is 158,617 ac-ft, which yields approximately 64,960 ac-ft per year (58 mgd) for water supply. In addition, the COE adopted a 100,800 ac-ft per year (90 mgd) water quality release program as a mitigation measure for Red River water quality requirements downstream from Hugo. Hugo storage allocation between flood control, conservation, and inactive storage is summarized in Table 3-9.

TABLE 3-9
Hugo Reservoir Storage Allocation

Initial Storage Allocation	Elevation (ft)	Storage Capacity (ac-ft)
Flood Control	404.5 - 437.5	809,100
Conservation [a]	390.0 - 404.5	127,160
Inactive	352.0 - 390.0	24,739
Total	**352.0 - 437.5**	**960,999**

Note:
[a] Conservation Storage Yield = 58 mgd for water supply
Conservation Storage Yield = 90 mgd for downstream quality

Currently, there are six permits on file at OWRB for water supply from Hugo. These permits total to 63,723 ac-ft per year (56.9 mgd), leaving 1,273 ac-ft per year (1.1 mgd) unallocated and available for development. There are no pending applications for water supply from Hugo. Of the total permitted water supply yield, 62,500 acre feet per year (55.8 mgd) is allocated to two permit holders, Western Farmers Electric COOP (32,000 ac-ft per year) and the City of Hugo (30,500 ac-ft per year). Table 3-10 summarizes the water permits for Hugo that are on file with OWRB.

TABLE 3-10
Hugo Reservoir
Surface Water Permits [a]

Name	Permit Number	Permit Amount (ac-ft/yr)	Reported Use [b] (ac-ft/yr)	Purpose
Hugo Municipal Authority	19540795	1,700	943	Public Water Supply
	19720048	28,800	0	
City of Antlers	19720060	523	232	Industrial
Western Farmers Elec. COOP	19770160	32,000	5,454	Power
Pushmataha Co RWD No. 3	19920022	400	464	Public Water Supply
	19930017	300	0	
Total		**63,723**	**7,093**	

Note:
[a] Adopted from OWRB - *Kiamichi River Basin Water Resources Development Plan; Interim Report*
[b] Reported 1998 water use.

Based on reported water use in 1998, the City of Hugo only used approximately 3 percent of its total permitted water supply. Whereas, the Western Farmers Electric COOP only used 17 percent of its total permitted water supply. A task under Kiamichi River Basin Development Plan (HCR 1066) is to investigate measures to aid the City of Hugo in satisfying its long-term debt obligation with the COE for water storage in Hugo. As with most COE construction contracts, the City of Hugo was allocated water storage based on Current Use and Future Use appropriations. The City of Hugo contracted with the COE for 1,640 ac-ft of water storage as Current Use and 18,880 ac-ft as Future Use. The City of Hugo has indicated to the Kiamichi Working Group that water from Hugo Reservoir not believed to be needed to meet local growth needs could be utilized for development of the Kiamichi River Basin. In other words, the City of Hugo is interested in selling a portion of their water storage and supply rights. OWRB also indicated that the Western Farmers Electric COOP has indicated the potential for relinquishing a portion of their water rights. Although the potential to buy permitted water supply from these entities has been discussed, specific details have not been formally proposed.

A potential alternative for the City of Norman is to purchase water storage and supply rights from the Western Farmers Electric COOP and/or the City of Hugo to meet Norman's long-term water needs. This alternative would involve obtaining water rights from the two entities equivalent to 33,600 ac-ft per year (30 mgd) to Hugo Reservoir. Considering the total permitted water rights between the two entities (62,500 ac-ft per year), this would result in the City of Norman securing approximately 54 percent of the total supply permitted to the two entities. Alternatively, the City of Norman could obtain 32,327 ac-ft per year (28.9 mgd) from the two entities along with the currently unallocated water supply yield of 1,273 ac-ft per year (1.1 mgd). With this alternative, the City of Norman would obtain approximately 52 percent of the Western Farmers Electric COOP and the City of Hugo permitted water supply. Although 52 (or 54) percent is a significant amount, the two entities only used a combined 10 percent (6,397 ac-ft) in 1998 of the total permitted supply (62,500 ac-ft per year). If Norman developed the full 33,600 ac-ft per year, the two entities would have a combined total of 28,900 ac-ft per year (25.8 mgd), or 4.5 times their 1998 water use demand, to meet their current and future water needs. Actual water rights obtained from each entity would be based on mutual agreements between the City of Norman, City of Hugo, and the Western Farmers Electric COOP.

Regarding the alternative discussed above, the City of Norman would likely purchase water storage capacity in Hugo associated with the water supply yield, thereby relieving the current owners of construction debt obligations. The City of Norman would purchase an estimated 24,623 ac-ft of storage capacity in Hugo Reservoir, which would yield 33,600 ac-ft per year (30 mgd). Based on general debt service information on file with the COE, the current cost for this storage capacity would likely be $3.6 million. In addition to these capital costs, annual O&M costs must also be considered. O&M costs are based on the proportion of storage purchased by the City, in relation to the total available storage capacity (conservation + flood pool). Based on preliminary evaluation and estimates by the COE, the City would be responsible for 8.3 percent of total O&M ($870,000) or $72,210 annually.

Another alternative for Hugo Reservoir is the potential to raise the conservation storage top of pool elevation 5 feet. Based on information from OWRB and the COE, the Hugo Reservoir conservation pool was authorized to be raised from elevation 404.5 feet to elevation 409.5 feet if the need for water supply developed. With the conservation pool raised, an estimated additional 88 mgd of water supply yield would be available. With raising the conservation pool, a reallocation between flood control and conservation would be realized. Associated with this reallocation would be the debt service for storage capacity, based on updates of initial construction cost to present day values. Additional costs associated with raising the conservation pool could include tribal rights issues, environmental concerns, and recreation facilities relocation. In 1997, the COE developed a preliminary planning level cost opinion on the order of $10 to $20 million for re-allocating storage capacity in Hugo Reservoir. Considering the potential to purchase existing conservation storage capacity from the Western Farmers Electric COOP and/or the City of Hugo, this alternative of re-allocating flood control storage to conservation storage is not developed further in this strategic plan. However, if the City of Norman were to exercise this option, Hugo Reservoir holds the ability for additional water supply well beyond the 40-year planning horizon.

Similar to other Southeast Oklahoma water supply sources, conveyance infrastructure would be required to transfer water from Hugo to Norman. The potential could exist for the City of Norman to lease or purchase capacity on the next OKC Atoka/McGee Creek conveyance system expansion. If one of these alternatives could be negotiated with OKC, water supply from Hugo Reservoir would be routed to McGee Creek via a new conveyance line. From McGee Creek, existing or modified infrastructure would be utilized to route flow from McGee Creek Reservoir to Lake Thunderbird. Further development and consideration of this option follows in Section 3.3.

Planned Parker Reservoir

Parker Reservoir, a multi-purpose reservoir, was authorized by the Water Resources Development Act of 1986. The project is for impoundment of Muddy Boggy Creek near Ada in Southeastern Oklahoma (Coal County). The COE estimated Parker Reservoir would ultimately provide 110,300 ac-ft of flood control storage and 109,940 ac-ft of conservation storage. Yield from the conservation storage is estimated at 45,900 ac-ft per year (41 mgd). Although preconstruction engineering and design have been completed for this project, construction of Parker Reservoir is on hold until a local sponsor for the conservation storage is secured. Table 3-11 summarizes the authorized project data pertinent to Parker Reservoir.

TABLE 3-11
Parker Reservoir
Authorized Storage Allocation

Storage Allocation	Initial Condition Storage (ac-ft)	Ultimate Condition [a] Storage (ac-ft)
Flood Control	110,650	110,300
Conservation [b]	114,640	109,940
Inactive	6,940	0
Total	**232,230**	**220,240**

Note:
[a] After 100 years sediment accumulation
[b] Initial Conservation Storage Yield = 42 mgd
Ultimate Conservation Storage Yield = 41 mgd

Development of Parker Reservoir was a potential alternative evaluated under the City of Norman's *Water Master Plan (1992)*. As reported in the previous study, several municipalities and operating agencies, including the COMCD, who currently operates Lake Thunderbird, were potentially interested in developing portions of this supply during the planning phase.

The Cities of Ada, Tecumseh, Shawnee, and Moore as well as the COMCD and OWRB initially reported a preliminary level of interest in Parker Reservoir. However, the current level of interest among the original municipalities and operating agencies is uncertain.

As construction of Parker Reservoir is pending funding from a local entity for the conservation storage, the potential exists for the City of Norman to purchase water supply storage in Parker Reservoir, and thereby allow construction to begin on the project. The estimated conservation storage yield of 41 mgd exceeds the projected additional water supply capacity needs targeted for Year 2040. As such, Norman could potentially reserve storage equal to 33,600 ac-ft per year (30 mgd) yield and develop a partnership with one or more interested parties in Parker for the remaining storage, yield, and debt service. Alternatively, the City of Norman could reserve the entire conservation storage and yield to meet water demands beyond the 40-year planning horizon.

Based on the initial (1989) project data, Table 3-12 summarizes the estimated current construction cost (updated using ENR construction costs indices) for Parker Reservoir.

TABLE 3-12
Parker Reservoir
Estimated Current Project Cost [a]

Purpose	Total Estimated Cost (x $1,000)	Non-Federal Cost (x $1,000)	Federal Cost (x $1,000)
Flood Control	3,946	1,973	1,973
Water Supply	78,254	78,254	N/A [b]
Total	**82,200**	**80,227**	**1,973**

Note:
[a] Based on *Parker Lake, OWRB (1989)*. Cost updated to present value based on ENR cost indices.
[b] N/A – Not Applicable

As shown in Table 3-12, non-federal cost apportionment would be costs associated with purchasing conservation storage and yield. The City of Norman would realize full non-federal costs for development of the conservation storage, unless the City could develop a partnership with other Central Oklahoma communities in the project. Federal cost allocation is estimated at $1.9 million, or 2.4 percent of the total project cost. However, flood control storage is equal to 50 percent of the total ultimate storage capacity of Parker Reservoir. For development of this alternative, it would be beneficial to renegotiate the initial federal and non-federal cost allocations to align more with storage capacity allocation for flood control (federal) and conservation (non-federal).

As discussed in the previous study, development of Parker Reservoir considered a 39-inch-diameter pipeline to convey raw water from the outlet of the reservoir to OKC's existing Atoka conveyance pipeline. The Atoka pipeline would route water to Lake Thunderbird, diverting to the lake where it passes the Hog Creek branch. Existing or modified facilities at Lake Thunderbird would allow COMCD to distribute the additional water supply to the City of Norman.

This alternative is only viable as a long-term (20+ years) source due to the required timing for construction of the new reservoir and associated conveyance infrastructure. Conveyance capacity in the existing Atoka pipeline must also be negotiated with OKC. If capacity on the Atoka pipeline cannot be leased or purchased, then the new conveyance system would be required to transfer water supply to Norman. Based on discussion with City staff and results from the previous Master Plan, Parker Reservoir is discounted from further development under this Strategic Water Supply Plan.

South Canadian River

The South Canadian River represents an undeveloped local water resource for the City of Norman. However, water is generally of poor quality, especially during periods of low flow. Development of this water resource has been considered in the past, most recently in the *1992 Water Master Plan*, but was discounted from development because of poor water quality. However, a new review of this alternative is necessary due to the increasing importance of securing additional water resources and the emergence of membrane technologies for water treatment.

The South Canadian River forms the west and south boundaries of the City of Norman. It originates in New Mexico, flows through the Texas panhandle, and across Oklahoma, where it terminates in Robert S. Kerr Reservoir in Southeast Oklahoma. Before its confluence, the South Canadian River feeds five major water impoundments along its flow route:

- Ute Reservoir, New Mexico
- Conchas Lake, New Mexico
- Lake Meredith, Texas
- Eufaula Lake, Oklahoma
- Robert S. Kerr Reservoir, Oklahoma

To ascertain water flows in the South Canadian River, arithmetic mean daily flow records were adopted from the USGS archives. USGS flow data were obtained for six gauging stations on the South Canadian River. Flow data is not continuous for every station, most likely due to limited USGS project funds and/or project operating plans. Table 3-13 characterizes each of the six USGS gauging stations along the South Canadian River.

TABLE 3-13
USGS Stream Gauge Stations: South Canadian River

Gauge Station: Near	Gauge Station: Number	County	Basin Name	Drainage Area (mi^2)	Datum (ft above NGVD)	Available Flow Data
Bridgeport, OK	7228500	Caddo	Lower Canadian Walnut	25,276	1,360	1944-1999
New Castle, OK	7229000	McClain	Lower Canadian Walnut	25,763	1,146.75	1939-1945
Norman, OK	7229050	Cleveland	Lower Canadian Walnut	N/A[a]	1,083.7	1995-1999
Noble, OK	7229100	McClain	Lower Canadian Walnut	25,911	1,045.29	1960-1961 1964-1975
Purcell, OK	7229200	McClain	Lower Canadian Walnut	25,939	1,017.14	1959-1961 1979-1983 1985-1999
Calvin, OK	7231500	Hughes	Lower Canadian Walnut	27,952	682.72	1944-1999

[a] N/A – Not Available

To characterize South Canadian River flows, focus was given to river flows upstream of the City of Norman. To this end, data adopted from the gauging station near Bridgeport, Oklahoma, provides the most complete data set from the available flow data for the South Canadian River. The following paragraphs present an evaluation of the water quality and flow data.

Water Quality. Water supply from the South Canadian River is of relatively poor quality. Available water-quality data from the USGS is sporadic for locations along the South Canadian River. For this analysis, water-quality data was adopted from a sampling location near Bridgeport. Data from January 1979 through May 1992 was available for review and included TDS and chloride concentrations. Table 3-14 summarizes water quality of the South Canadian River with respect to these constituents.

TABLE 3-14
South Canadian River
Water Quality

Parameter	TDS	Chloride
Number of Samples[a]	146	147
Maximum (mg/L)	1,810	490
Minimum (mg/L)	270	17
Flow Weighted Average (mg/L)	1,167	234

Note:
[a] Data adopted from USGS. Data represents water quality sampling from January 1979 through May 1992.

Comparing water-quality data with typical standards for classifying water supply based on TDS concentrations, the South Canadian River with an average TDS concentration of approximately 1,200 mg/L could be classified as a fresh (zero to 1,000 mg/L) to brackish (1,000 to 10,000 mg/L) raw-water supply. Both chloride and TDS concentrations for finished water are addressed under the SDWA as secondary regulations. The secondary standards for TDS and chlorides, respectively, are 500 mg/L and 250 mg/L. Secondary standards for finished water are associated with aesthetic quality parameters, not health-related. Accordingly, the SDWA encourages water systems to meet water-quality goals set under the secondary levels, but these goals are not automatic rejection levels. Nevertheless, consumer confidence and acceptance of finished water is dependent on finished-water quality, including aesthetics. To some extent, aesthetic issues are relative to consumer sensitivity, which in turn is related to the degree to which the consumer is accustomed. Additionally, unacceptable finished water TDS levels can have negative impacts on water-purveyor and end-user water system operations. Table 3-15 presents TDS levels in the City's existing water resources for comparison to the South Canadian River water quality.

TABLE 3-15
Water Resource
Average TDS Concentrations

Water Source	TDS (mg/L)
Lake Thunderbird Raw Water	150 - 250
Garber-Wellington Aquifer	240 - 370
South Canadian River	905 – 1,326

Development of the South Canadian River as a water-supply source warrants mitigation measures for removing TDS. Mitigation measures can include advanced treatment barriers (discussed in the following section), raw-water quality management, or both. Raw-water quality management could potentially include targeting diversion from the river when water quality is relatively high. Another alternative could include blending raw water from the South Canadian River with another higher water-quality source, such as Lake Thunderbird raw water.

Daily Flows. Water flow in the South Canadian River is highly variable. Considering mean daily flows at the Bridgeport, Oklahoma, gauging station during the last 20 years (from January 1979 through September 1999), daily flows ranged from zero to 27,197 mgd. Daily flows at the Bridgeport Station are summarized in Table 3-16 and depicted on Figure 3-5.

TABLE 3-16
Bridgeport Station
Daily Flow Summary

Daily Average Flow	Number of Days	Percent
Less than 10 mgd	855	11
10 to 100 mgd	2,796	37
100 to 1,000 mgd	3,697	49
1,000 to 10,000 mgd	222	3
Greater than 10,000 mgd	8	< 0.2

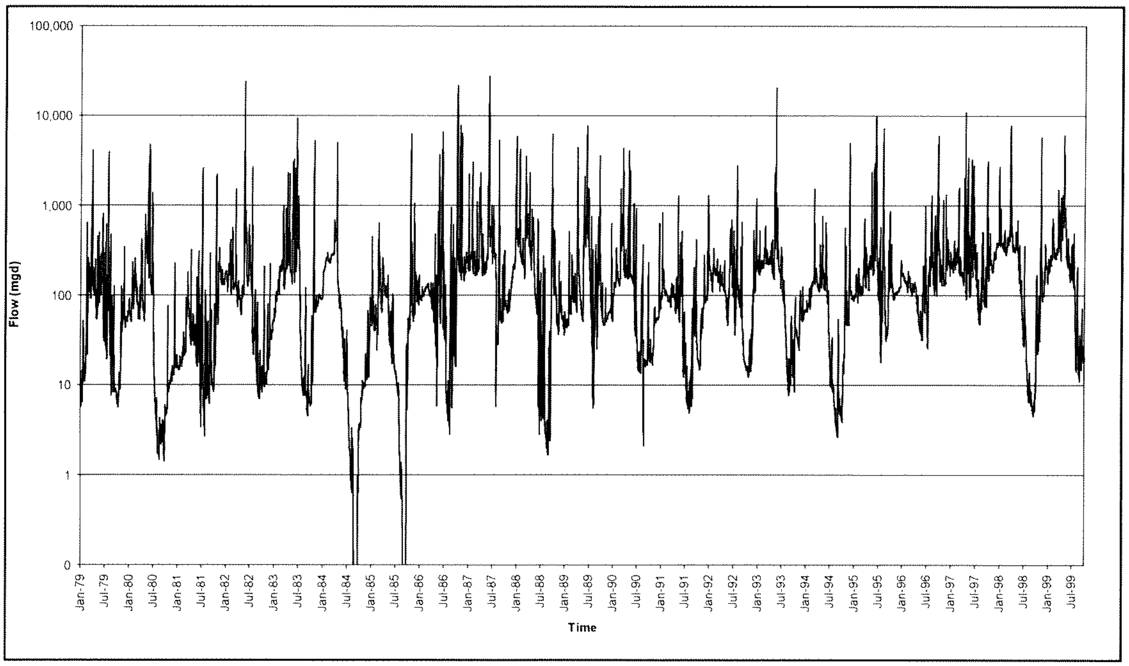


FIGURE 3-5
South Canadian River Mean Daily Flows
Gauging Station at Bridgeport

As shown, the South Canadian River has, at times, significant quantities of flow. Consideration to the occurrence and duration of these flows is critical for developing the South Canadian as a water supply source. Water diversion capacity will be dependent on adequate flow and the duration of such flows. Storage capacity will be required for time intervals when river flows cannot support diverting water supply. South Canadian River daily intervals of flow for the 1979 through 1999 record are provided in Table 3-17.

TABLE 3-17
South Canadian River
Average Daily Flow Duration

Year	Greatest Number of Consecutive Days (days) Average River Flow			
	< 10 mgd	< 100 mgd	> 100 mgd	> 1,000 mgd
1979 –1980	34	57	25	3
1980-1981	97	163	64	5
1981-1982	16	96	141	2
1982-1983	16	66	71	5
1983-1984	21	59	170	7
1984-1985	114	242	121	1
1985-1986	72	162	29	1
1986-1987	17	38	46	7
1987-1988	1	30	300	7
1988-1989	33	57	185	8
1989-1990	2	44	57	4
1990-1991	1	80	160	2
1991-1992	22	83	37	1
1992-1993	0	84	138	1
1993-1994	6	121	226	4
1994-1995	42	124	116	2
1995-1996	0	25	151	10
1996-1997	0	36	128	7
1997-1998	0	15	286	4
1998-1999	46	92	257	7
1999[a]	0	54	235	4

Note:
[a] Data represents daily flows from January 1999 through September 1999.

As evidenced by the number of consecutive days with flow below 10 mgd, raw water storage would be required to develop the South Canadian River as a raw water supply source. Conversely, there are a significant number of consecutive days in which water from the South Canadian River could be diverted to support such a practice.

Monthly Flows. Monthly-average flows (total flow per month divided by number of days per month) were calculated based on the daily flows for the gauging station at Bridgeport. Monthly flows are considered in light of the seasonal water demands experienced by the City of Norman's water supply system. Similar to demands on the water system, river flows are dependent on seasonal variations in weather patterns. Storage volume is required to meet water production needs if water is not available for diversion from the South Canadian River to meet the varying seasonal water demands.

South Canadian River monthly-average flows ranged from 0.7 to 2,706 mgd. Table 3-18 briefly summarizes the South Canadian River monthly-average flow occurrences at Bridgeport for the total 249 months studied.

TABLE 3-18
South Canadian River
Monthly-Average Flows

Monthly Average Flow	Number of Months	Percent
Less than 10 mgd	16	6
10 to 100 mgd	85	34
100 to 200 mgd	59	24
200 to 500 mgd	61	25
Greater than 500 mgd	28	11

Table 3-19 presents the maximum and minimum monthly-average flows for each year in the data record. Also, the average flow 95 percent confidence interval (meaning 95 percent of the data falls in the presented interval) is provided to illustrate flow variations for each respective month. Maximum-month flows inherently have a greater average-flow interval, largely due to variables such as occurrence, duration, and intensity of wet-weather events.

TABLE 3-19
South Canadian River
Monthly Average Flows: Gauging Station at Bridgeport. Oklahoma

	Maximum Month			Minimum Month		
Year	Month	Mean Flow(mgd)	Average Flow 95% Confidence Interval (mgd)	Month	Mean Flow (mgd)	Average Flow 95% Confidence Interval (mgd)
1979	March	445	169 to 721	Oct	14	6 to 22
1980	May	403	395 to 508	Aug	2	1.9 to 2.4

TABLE 3-19
South Canadian River
Monthly Average Flows: Gauging Station at Bridgeport. Oklahoma

Year	Maximum Month			Minimum Month		
	Month	Mean Flow(mgd)	Average Flow 95% Confidence Interval (mgd)	Month	Mean Flow (mgd)	Average Flow 95% Confidence Interval (mgd)
1981	Oct	206	29 to 382	Aug	16	11 to 22
1982	May	1,578	86 to 3,069	Sept	11	9 to 12
1983	June	1,429	656 to 2,203	Sept	7	6 to 8
1984	April	438	124 to 752	Sept	0.7	0.3 to 1.2
1985	Oct	384	0 to 778	Aug	0.7	0.5 to 0.9
1986	Oct	1,558	147 to 2,970	July	24	14 to 33
1987	May	2,706	513 to 4,898	Oct	78	75 to 81
1988	March	931	678 to 1,183	Aug	3	2.6 to 3.3
1989	June	1,376	695 to 2,057	Nov	58	57 to 60
1990	March	479	218 to 740	Oct	22	21 to 23
1991	Dec	232	136 to 328	July	11	9 to 13
1992	June	285	227 to 343	Oct	16	14 to 17
1993	May	1,634	277 to 2,991	Aug	15	13 to 17
1994	Nov	384	43 to 725	Aug	4.8	4.1 to 5.5
1995	June	1,513	644 to 2,381	July	94	59 to 130
1996	Sept	895	381 to 1,410	May	52	45 to 60
1997	April	1,160	371 to 1,948	July	113	94 to 132
1998	March	1,193	576 to 1,811	Sept	6.2	5.6 to 6.8
1999 [a]	April	1,086	639 to 1,534	Sept	24	19 to 28

Notes:
[a] Data represent daily flows from January 1999 through September 1999.

Review of monthly data over the 20-year study period shows the South Canadian River typically has the greatest flow during the spring months (March through June). Low flows typically occur during the summer months (July through September). Considering water demands on the water system, these flow patterns are inverse to the potable water demands, as the system typically experiences peak water demands during the summer and lower demands during the spring. However based on the 20-year average-monthly flows, the South Canadian River average flow is typically greater than 100 mgd ten months of the year although daily flows are less than 100 mgd 48 percent of the time. This difference is due to high daily flows (1,000 to 10,000) increasing the monthly-average flow results. Figure

3-6 represents the 20-year monthly-average flows between 1979 and 1999 for the South Canadian River.

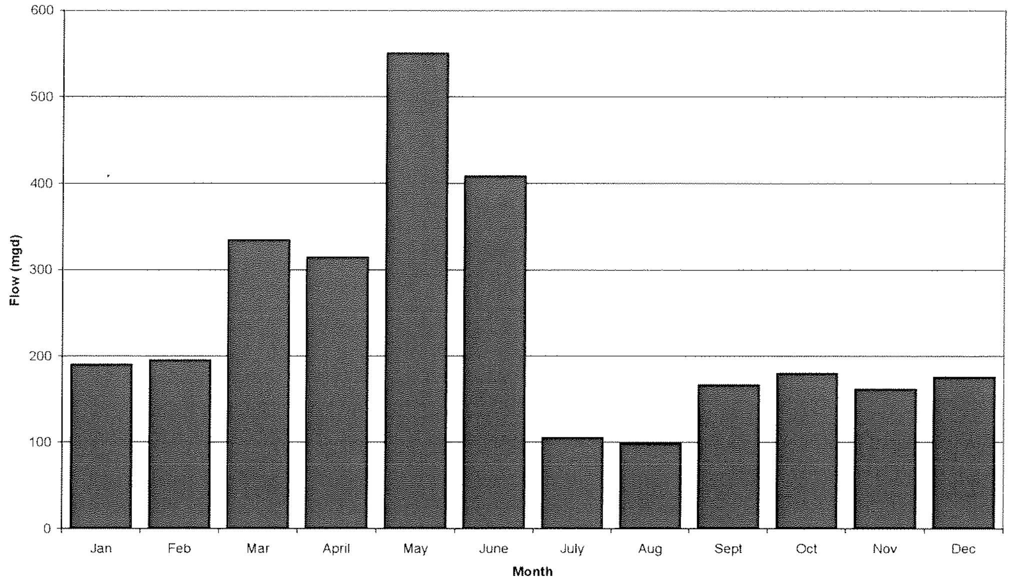


FIGURE 3-6
South Canadian River 20-Year Monthly Average Flows
Gauging Station at Bridgeport

Annual Flows. Figure 3-7 depicts annual-average flows (total flow per year divided by 365 days) of the South Canadian River at the Bridgeport gauging station. Annual-average flow represents the maximum yield of the river, which to some degree would be available to support a potential South Canadian River raw water supply system. Additionally, water right permits are based on volume of water per year.

The 20-year average-annual flow at Bridgeport is 241 mgd. Annual-average flows for the 20-year study period are summarized in Table 3-20.

TABLE 3-20
Bridgeport Annual Average Flows
1979 - 1999

Annual Average Flow	Number of Years	Percent
Less than 100 mgd	3	15
100 to 200 mgd	6	30
200 to 400 mgd	8	40
Greater than 400 mgd	3	15

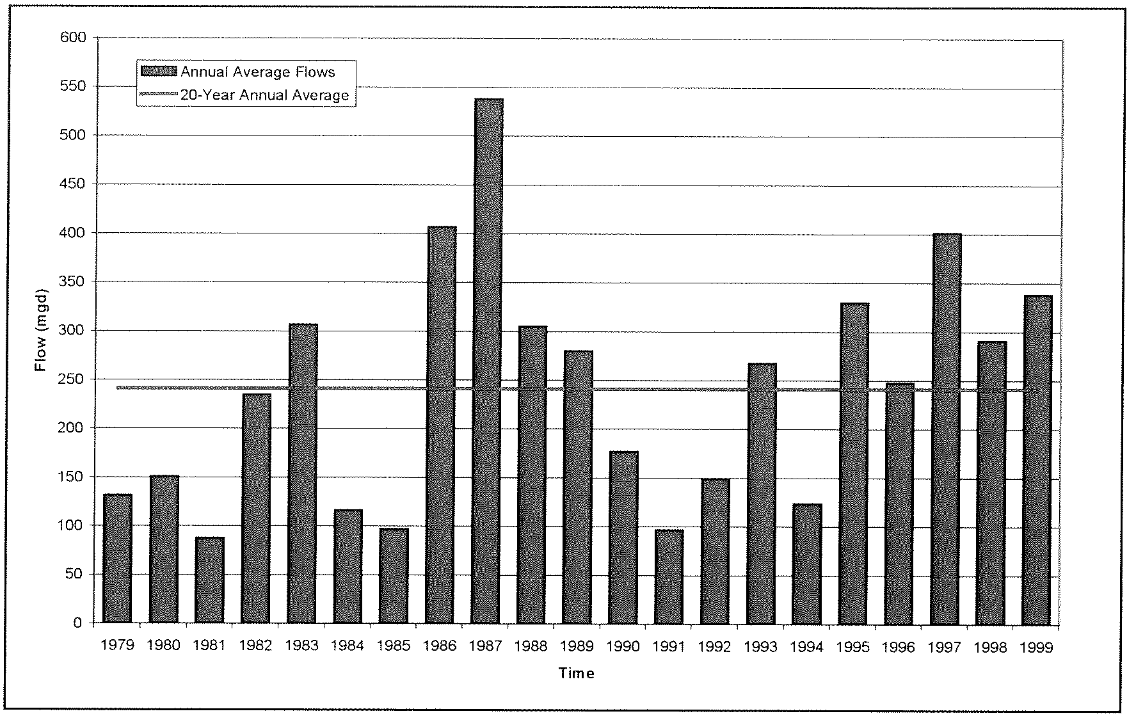


FIGURE 3-7
South Canadian River Annual Average Flows
Gauging Station at Bridgeport

The total annual-average flow of the South Canadian River is typically well beyond the additional water resource needs of the City of Norman over the foreseeable planning horizon. Although, total yield of the river would not be available for diversion due to variability in daily flows and existing water rights, permits, and uses.

Water Rights, Use, and Permits. Water available from the South Canadian River to support a potential raw water supply system for the City of Norman will be dependent on existing water rights, permits, and uses. To ascertain the available water for appropriation, information was provided from the OWRB for the South Canadian River flowing from Bridgeport to Calvin, Oklahoma. Information for this river run was requested as this reach corresponds to USGS gauging stations and is considered sufficient to identify upstream and downstream (from Norman) water right permits and uses.

OWRB provided existing water-right permits, domestic uses, and quantity of water available for appropriation for two drainage basins serving two potential diversion points on the South Canadian River. These two diversion points were identified only to define boundaries along the South Canadian River pertinent to this study. Water rights and uses were identified for a 752.7-square-mile area draining to a reach of the South Canadian River running from Bridgeport to Purcell, Oklahoma. The second drainage basin was a 2,859.5-square-mile area draining to the South Canadian River from south of Purcell to Calvin, Oklahoma.

To develop the South Canadian River as a raw water supply, water would likely be diverted near Norman. Thus, focus was given to the South Canadian River reach running from

Bridgeport to Purcell, Oklahoma. Table 3-21 summarizes the information provided by OWRB for this river reach.

TABLE 3-21
South Canadian River
Water Available for Appropriation at a Diversion Point Near Purcell, OK

Description	Total (ac-ft/yr)	Total (mgd)
Total Water Available	118,208	105.5
Existing Permitted Use	8,636	7.7
Existing Domestic Use	18,064	16.1
Water Available for Appropriation	91,508	81.7

Note:
Data adopted from OWRB.

In addition to existing water rights and uses, data was obtained from ODEQ regarding point source discharges into the South Canadian River running from Bridgeport to Calvin, Oklahoma. For this river run, ODEQ identified a total of 20 facilities with discharge monitoring data and permits on file. For each facility, ODEQ provided Discharge Monitoring Reports from January 1995 through April 2000 and the seven-day low-flow criteria (7Q2) identified within the OWRB Water Quality Management Plan for each permit reach. 7Q2 is defined as a two-year average of seven consecutive days of the lowest flow for the river. Therefore, a new 7Q2 can be defined each year for a given stream segment. Table 3-22 summarizes permit and facility data on file with ODEQ for the 10 discharge permits between Bridgeport and Purcell. The highest 7Q2 permit criteria for facilities downstream of Purcell is also included, as this represents the critical river flow requirements needed by facilities downstream to maintain existing discharge permits.

TABLE 3-22
South Canadian River
Facility Permits and Discharges from Bridgeport, OK to Purcell, OK

Description	Total
Number of Facilities	10
Annual Average Discharge[a]	20 mgd
7-day Maximum Discharge (Average)[1]	30 mgd
Low 7Q2[b]	0 mgd
High 7Q2[b]	2.6 mgd
Downstream High 7Q2	2.46 mgd

Notes: Data adopted from ODEQ.
[a] Discharge data represents total flows from the 10 facilities. Flow from each facility is based on a 5-year average (January 1995 – April 2000).
[b] Represents permitted extreme for reach of interest.

Considering evaluation of the data provided by USGS, OWRB, and ODEQ, water-right permits are available to support a potential South Canadian River raw water supply system. Although water rights are available, the actual quantity of water that could be reliably diverted over any given year is dependent on actual river flows. Additionally, water diversion would need to be managed to effectively mitigate potential negative impacts to existing water use and discharge permits. In short, the rate and duration of water supply diversion will be dependent on sufficient daily-flow events when the river can support a diversion practice while satisfying existing permits and uses. These considered the total flow of the South Canadian River presented in the previous paragraphs is considered "gross" river flows.

Construction of an off-channel reservoir near the South Canadian River could capture a fairly reliable water resource for the City. Historic flows illustrate that adequate flow is available. However, a review of water quality data indicates that advanced treatment processes would be required. As such, this option offers the greatest potential for an undeveloped local surface water resource to meet the City of Norman's demands for the 40-year planning horizon and beyond. Further development and consideration of this option follows.

3.2.5 Water Purchase

As discussed under Section 3.2.4, New Surface Water Resources, the potential exists for Norman to develop partnerships with other Central Oklahoma communities to develop water resources and conveyance infrastructure. Another possibility for the City Norman is to purchase water supply from local communities. Of all Central Oklahoma communities, only OKC has adequate water supply for sale to meet the projected needs of Norman. Oklahoma City currently owns water rights to the North Canadian and Southeast Oklahoma water resources. Through these resources and associated infrastructure, OKC is well positioned to meet their current as well as future inside and outside water consumption demands. As such, OKC has indicated willingness to wholesale either treated water or raw water on a unit basis to the City of Norman. Although some level of control is lost as compared to partnering in water resource ownership, water purchase agreements are generally less complex to manage than a comprehensive capital improvements program for new water system infrastructure. Furthermore, purchase agreements are more conducive for matching actual needs than investment in a new water resource that may not be fully realized until some time in the future. For the planning horizon, three water purchase agreement options have been identified for consideration in this Strategic Water Supply Plan. These alternatives are discussed in the following paragraphs.

OKC Treated Water—Base Supply

This alternative involves the purchase of treated water from OKC for distribution by Norman to meet annual-average and maximum-day demands. Water obtained from OKC would be treated surface water from Southeast Oklahoma via Draper WTP. Oklahoma City would be responsible for the raw water, conveyance, treatment, and transmission (delivery to Norman) costs. However, such costs would be indirectly passed to the City through unit purchase costs. Unit cost for OKC treated water as a base supply is currently $1.65 per thousand gallons. This unit cost is expected to increase by 3 percent annually over the planning horizon due to inflation.

Treated water from OKC is considered good quality water. As such, this alternative is not expected to require that the City provide any additional level of treatment (i.e. coagulation, softening, sedimentation, filtration, and disinfection) as for raw surface water. Additionally, both Oklahoma City and Norman use chloramines for residual disinfectant in the distribution system. Therefore, disinfectant residual maintenance and potential disinfection by-products formation should not increase with implementation of this alternative. On the other hand, this water supply will be characteristically different than treated water produced from the City's existing system. Particulate precipitation and taste and odor issues may arise from mixing dissimilar waters. Although these issues are relatively minor, bench-scale blending may be warranted to more fully evaluate compatibility.

A primary concern with this alternative is the long-term availability of water supply. The reliability of this alternative is highly dependent on stipulations of the water purchase agreement. Rates, terms, and conditions of any treated water supply purchase agreement will have to be negotiated. In any event, this alternative will be considered for the planning horizon. Additionally, this alternative will also be considered as a short- to mid-term "contingency" water supply as other potential water source alternatives are developed.

OKC Treated Water—Peak Supply

The City of Norman recently (September 1999) entered a 5-year purchase agreement with Oklahoma City for treated water peaking supply. This peak water supply is targeted to augment the City's system in satisfying maximum-day and peak-hour water consumption demands. Maximum-day demand is the primary driver for sizing treatment and finished water transmission (pumping facilities and piping) infrastructure capacity. Additionally, peak-hour demand is the primary driver for sizing in-system distribution storage facilities. Furthermore, this infrastructure must be in place to meet these peak demands, but operation is governed by seasonal and daily fluctuations in demands. Accordingly, required infrastructure and operation of water supply facilities in meeting peak demands effectively drive the unit cost up for production and delivery. As such, purchasing peak water supply inherently has a greater unit cost, as compared to purchasing base supply. Unit cost for OKC treated water as a peaking supply is currently $2.51 per thousand gallons. Similar to base supply, this unit cost is expected to increase over the planning horizon due to inflation. Based on the City of Norman's existing purchase agreement, water rates are expected to increase 3 percent per year.

For the planning horizon, this alternative will consider extending the treated water peaking supply purchase agreement. As discussed previously, water supply under this alternative is targeted to meet maximum-day water consumption demands. Water treatment and production infrastructure capacities are driven by maximum-day demands. As such, this alternative can offset infrastructure capacity needs for the City. With this in mind, purchasing OKC treated water as a peaking supply will be considered as an alternative for augmenting maximum-day production from the City's water system.

OKC Raw Water

The City of Oklahoma City owns the water rights for the Atoka and McGee Creek Reservoirs, as well as the associated raw water conveyance pipelines. As previously discussed, raw water is pumped from McGee Creek and Atoka to Lake Stanley Draper for storage, treatment, and distribution to the service population of OKC. The City could develop a wholesale purchase agreement to obtain raw water from the pipeline. Although this option does not secure any additional water rights for the City, it does increase available water supply and allow the City to meet future demands. However, this option would leave the City dependent on OKC for its water supply. The unit rate to purchase raw water from OKC is currently $0.83 per thousand gallons. This cost is based on OKC pumping from Atoka Reservoir. If OKC utilizes raw water from McGee Creek, the unit cost is expected to increase to $0.91 per thousand gallons as additional pumpage would be realized. Similar to wholesale purchase of treated water, the unit cost for raw water is expected to increase 3 percent per year over the planning horizon.

The raw water conveyance pipeline, or Atoka/McGee pipeline, does not currently flow at capacity to meet system demands. The pipeline was designed for a full-flow capacity of 90 mgd, although the installed pumps currently limit the operating capacity to 60 mgd. On a historical basis, an average of about 50 mgd is pumped through the conveyance line. Therefore approximately 10 mgd of additional conveyance is available in the pipeline without expansion improvements to the pumps or associated equipment. Higher capacity pumps could allow for additional pumping capacity (up to 90 mgd) in the pipeline. To meet Norman's long-term additional water supply needs, expansion improvements to the Atoka/McGee Creek conveyance system would likely be necessary over the planning horizon. Such cost would likely be incorporated in the unit purchase cost for raw water.

As previously discussed, the Atoka/McGee pipeline intersects Lake Thunderbird. Water supply from the conveyance pipeline could be released into Lake Thunderbird or to a new terminal reservoir and then transferred to Norman's WTP for treatment prior to distribution. Expansion of the raw water conveyance system from Lake Thunderbird and expansion of the WTP would be required to realize this additional water supply. This considered, the purchase of raw water from OKC's Southeast Oklahoma supply will be evaluated further for this Strategic Water Supply Plan.

3.2.6 Water Reclamation

Water reuse is the process of reclaiming wastewater treatment plant effluent for beneficial uses. Strategies for reclamation may include direct non-potable systems such as urban and agricultural irrigation. In recent years, a number of municipalities have considered the use of highly treated reclaimed water for use in augmenting raw water supplies. Historically, wastewater reclamation has been driven by increasingly stringent water quality requirements for discharge to receiving surface water bodies. As populations increase, the use of reclaimed water has become an important element of the water resources available. The logic of turning to reclaimed water as a means of meeting existing water demands can be based on consideration of fresh water demands such as public and domestic irrigation, industrial and commercial, thermoelectric, agricultural irrigation and water for livestock. While all of these uses require fresh water, it is reasonable to assume that not all demands must be met with water of potable quality. Figure 3-8 provides a summary of a recent reuse inventory conducted in Florida by use and customer type. It is apparent that non-potable demands have been identified for a wide variety of uses and significant conservation of potable resources is being realized. In response to this, many states have adopted regulations that acknowledge the value of reclaimed water and encourage its use where appropriate.

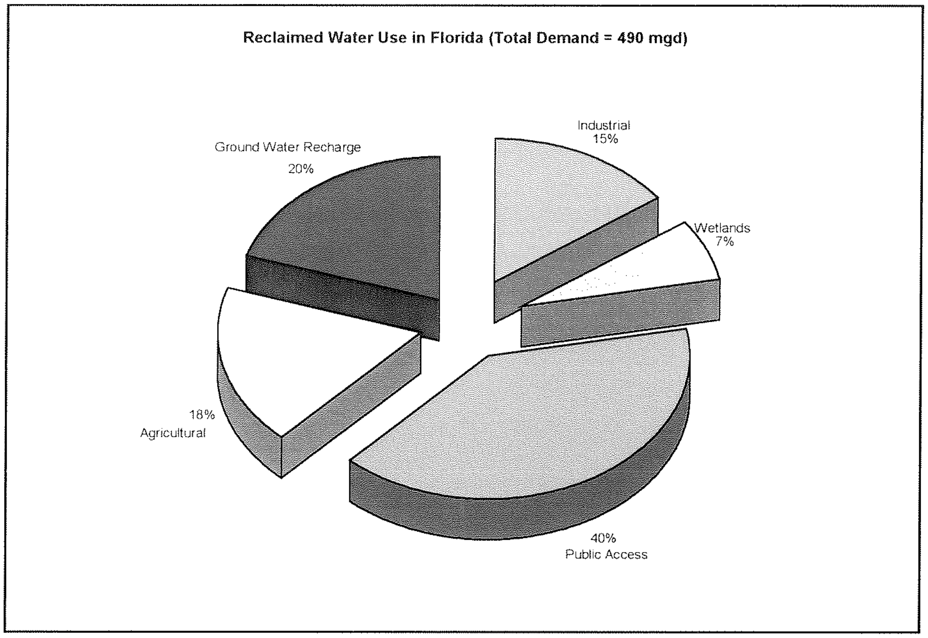


FIGURE 3-8
Reuse Inventory

Reuse water systems can provide substantial benefits to the City's potable water supply. For example, the use of potable water supplies for irrigation is often the primary cause of peak water demands. Because potable water systems must be able to meet peak demands, expansion of the potable water system may be largely driven by these non-potable water demands. The use of reclaimed water to meet non-potable water demands can provide conservation of potable water resources. Consequently, reuse systems can effectively defer costs associated with potable water systems, including water resources and infrastructure. The feasibility of reclaimed water systems is dependent on the potential savings to the potable water system.

Reclaimed water may also be used as a means of augmenting water resources. Though it is generally accepted that the technology exists to treat water to almost any quality, there remains a natural aversion to this practice. As such, public perception of indirect potable reuse systems is typically a limiting factor. Whether for direct non-potable or indirect potable reuse systems, it is not enough for engineers and policymakers to come to a consensus regarding which reuse alternative is the most feasible. There must be a consensus from the public. This is particularly true in areas such as Oklahoma where the practice of reclaiming wastewater is not common.

In addition to potential benefits to the potable water supply system, reuse strategies can benefit the City's wastewater management system. The end result of a reuse system could provide beneficial use of reclaimed water while reducing the amount of biochemical oxygen demand (BOD) and nutrients discharged to the South Canadian River. For the City of Norman, the wastewater treatment plant (WWTP) discharge permit is based on the BOD and nutrients loadings to the river. Reuse systems can be used to extend the useful life of the City's current NPDES permit without the need to expand treatment capacity at the WWTP.

Direct Non-Potable Reuse

The use of reclaimed water for urban and agricultural irrigation provides non-potable water for non-potable use. The use of reclaimed water for urban and agricultural irrigation has enjoyed a long and successful history. Early projects focused on restricted access irrigation primarily associated with effluent disposal. Over time, the emphasis has shifted to providing high-quality reclaimed water in place of other water sources as a means of conserving resources. With this shift comes the need to consistently provide high-quality water with respect to pathogens. Public access systems currently rely on filtration followed by disinfection to meet this objective. In addition to providing the appropriate treatment processes, reclamation systems often employ real-time monitoring to ensure water quality.

A recent article published in the *American Water Works Association Journal* (Volume 91, Issue 8) included a survey of 23 municipalities (in Arizona, California, Florida, Hawaii, and Texas) that currently operate direct non-potable reuse systems. As reported, most of the utilities serve customers irrigating large turf areas (golf courses, parks, and schools). Other uses included industrial power plants, car washes, and commercial retail application. Four of the 23 utilities reported significant reclamation water use for residential irrigation. The number of customers served by these reclamation projects ranged from 1,000 to 2,500. All 23 municipalities reported "good or very good" acceptance of the reclaimed water service by their customers. In one case, a utility reported that its customer connection demand exceeded the capacity of the available reuse water system. Noteworthy, connection to this system was based on a "first-come, first-serve" basis. Furthermore, most of the utilities reported to recover more than 75 percent of their reclaimed water system cost and all of their operating costs (in most cases). The 23 utilities included in the AWWA survey are identified below.

- Phoenix, AZ
- Tucson, AZ
- Burbank, CA
- Corte Madera, CA
- Costa Mesa, CA
- Glendale, CA
- Irvine, CA
- Long Beach, CA
- Los Angeles, CA
- Clearwater, FL
- Dunedin, FL
- Hollywood, FL
- Jupiter, FL
- Lake Buena Vista, FL
- Largo, FL
- Orlando, FL
- Palm Beach Gardens, FL
- St. Pete Beach, FL
- Sanford, FL
- Maui, Hawaii
- Austin, TX
- Irving, TX
- San Antonio, TX

With City staff input, a potential water reuse program under the *City of Norman Wastewater Master Plan Year 2000-2020* has been evaluated. The wastewater master plan evaluated operation of the existing University of Oklahoma Golf Course irrigation system, which uses reclaimed water from the City's WWTP. Additionally, the wastewater master plan identified several water reuse alternatives including urban irrigation (service to single- and multi-family homes), golf course and park irrigation, industrial reuse, wetlands, and surface water augmentation. From this long-list of alternatives, a program of providing reclaimed water to irrigate commercial properties on Highway 9 in Norman was identified for conceptual evaluation for the master plan 20-year planning horizon. Expanding irrigation sites is considered, in part, due to the success of the University of Oklahoma Golf Course irrigation system. Based on discussion with City and University of Oklahoma staff, this reuse strategy has benefited both the City and the University, although overall irrigation demand for this single site is low compared to total wastewater flows.

Based on existing irrigation water meters and proximity to the Norman WWTP, a reuse planning area was selected along Highway 9. Within this area, eight potential commercial sites were identified for an irrigation system utilizing reclaimed water. Metered irrigation use was provided for seven of the eight sites and estimated for the eighth site. These eight sites and their historical irrigation use are summarized in Table 3-23.

TABLE 3-23
Historical Water Use (Gallons/Month)

Site	Average	Maximum
Student Apartment Contractors	20,620	85,200
Senior Cottages of Norman	71,100	393,000
Total Landscape	105,911	641,200
Perfect Swing Limited	97,678	196,000
Shaklee	940,984	6,340,000
Hitachi	40,900	306,600
Hitachi Comp Prods, Inc.	133,564	776,500
Postal Center	100,000	200,000
Total (Gallons/Month) [a]	**1,510,757**	**8,938,500**
Monthly (gpd) [b]	**50,359**	**297,950**

Note:
[a] estimated irrigation demand
[b] Assumed 30 day month

If this irrigation demand were met through reclaimed water supply, a credit, or conservation in consumption of the potable water supply would be realized. This credit in potable water supply would subsequently be available to satisfy other demands. From the irrigation water use presented in Table 3-20, a monthly-average water supply credit of some 50,000 gallons per day could be realized from this potential reuse strategy. Additionally, a water supply credit of approximately 300,000 gallons per day could be realized on a maximum-month basis. Furthermore, the City would divert discharging this water to the South Canadian River, thereby extending the useful life of its current NPDES permit.

Noteworthy, reclaimed water to meet these irrigation demands is currently available, as the WWTP is currently treating an equivalent 10 mgd flow on annual-average basis. Preliminary evaluation of a reuse irrigation system (based on the existing University of Oklahoma Golf Course system) indicates that approximately 27 percent (2.7 mgd) of the WWTP current annual-average flow could be used for reuse projects without concern for seasonal shortages. However, treatment processes (disinfection facilities at the WWTP), transmission mains, pumping facilities, and reuse connections are not currently in place to delivery such supply. As such, infrastructure requirements would need to be implemented to fully realize this water supply credit.

Indirect Potable Reuse

Indirect potable reuse is unintentionally practiced through out the U.S. There are innumerable examples of treated wastewater discharges into watercourses that subsequently are used as water supply sources. Typically, the treated wastewater component is a small fraction of the total water supply to the resource. However, more than two dozen major water systems have raw water supply sources from rivers that receive wastewater discharge amounting to more than 50 percent of stream flow during low-flow conditions (as reported by the AWWA). Overall, these systems are considered as practicing "unplanned" indirect potable reuse. On the other hand, reclaimed water has been intentionally discharged into the raw water supply to increase the safe yield in a limited number of locations. An example of this practice would include Occoquan, Virginia, where reclaimed water is discharged into a surface water reservoir that is subsequently used as a raw water supply. During drought conditions reclaimed water may represent up to 90 percent of the inflow into the reservoir. Overall, there is currently less than a dozen existing "planned" indirect potable reuse projects in the U.S.

In recent years a number of municipalities including San Diego and Orange County California; Tampa and West Palm Beach, Florida; Denver, Colorado; and Scottsdale, Arizona; have conducted feasibility studies into the use of reclaimed water to augment potable supplies. Conditions common to all locations practicing or considering indirect potable reuse include:

- A demonstration that reclaimed water represents the next best source of potable water supplies
- A demonstration that direct non-potable reuse strategies (such as urban or agricultural irrigation) would not achieve conservation to the extent that additional potable water supplies are not required
- Treatment of the reclaimed water to drinking water standards or background quality of the receiving water is provided prior to discharge into the environment
- Reclaimed water is never discharged directly into the potable water distribution system. Rather it is released into surface waters or groundwater that ultimately becomes part of a community's potable water supplies.

Reclaimed water could be used to augment the City's surface water supply, Lake Thunderbird. The general approach for this alternative would be conveying treated effluent from the City's WWTP to Lake Thunderbird via a new pump station and conveyance line to Dave Blue Creek. Another possibility is the implementation of a new WWTP in the Little River drainage basin. Either of these scenarios would require advanced treatment of the wastewater (the existing WWTP provides secondary treatment) to provide high-quality effluent comparable to SDWA water-quality criteria. Lake Thunderbird would serve as a terminal reservoir for the reclaimed water and finished treatment at the WTP would be required prior to distribution. For conveyance of this additional supply from Lake

Thunderbird to the WTP, a new or modified raw water pump station and conveyance line would also be required.

Another indirect potable reuse alternative is recharging the GWA with reclaimed water. This reclaimed water would then become available for future withdrawals from the aquifer. Under this scenario the GWA would serve as seasonal storage for an aquifer storage and recovery system (ASR). Two potential scenarios are available to recharge the GWA: (1) utilize infiltration basins constructed in the recharge area; or (2) develop injection wells. Injection wells would be expected to receive more attention from both the regulators and the public, because little or no additional renovation of the reclaimed water would be expected between injection and extraction. Given this fact, and that the GWA serves as a source of potable supplies, a high level of treatment will be required prior to injection. Treatment processes required could include reverse osmosis and/or activated carbon. For infiltration basins, additional treatment could be gained naturally as the water passed through the soil. However, this type of recharge system would likely require secondary wastewater treatment, filtration, and disinfection (chlorination followed by de-chlorination) at a minimum prior to infiltration. Consideration would also have to be given to existing, privately owned wells tapping the unconfined aquifer. In both recharge scenarios, water extracted from the aquifer would likely require finish water treatment (such as disinfection) prior to distribution, as the reclaimed water would be considered an unprotected water supply.

For indirect potable reuse strategies, public, political, and regulatory ramifications must be considered for implementing either of these programs. In addition to the City, Lake Thunderbird also provides municipal water supply to the Cities of Midwest City and Del City. Additionally, the GWA supports numerous shallow, privately owned wells within Norman and is a supply source for surrounding municipalities. As such, acceptance of these potential reclamation programs will be highly dependent on public and political acceptance of such programs.

It is difficult to determine the political, public, and regulatory hurdles that such reuse programs will face. In general, the degree of public contact a reuse system involves can be used as a rough guide for the potential for public and regulatory opposition. A proposal to irrigate a restricted access commercial site would not be expected to attract much attention. The use of reclaimed water to augment potable water supplies, on the other hand, would be expected to generate a high level of scrutiny and potential opposition. Therefore, the analysis of reclaimed water programs cannot be made solely on its technical merits but must include consideration of how it will be received by the public. For example, in the past year, three proposed indirect potable reuse systems in the U.S. (groundwater injection program in California and surface water augmentation programs in California and Florida) did not gain approval due to public and/or political opposition. Noteworthy, indirect potable water reuse systems have been approved and are currently in operation in other locations in California (Los Angeles County and Fountain Valley). Also, several locations in California and Florida practice direct non-potable reuse (as identified in the previous section).

For the Strategic Water Supply Plan, indirect potable water reuse strategies are discounted for the planning horizon. Public and political acceptance of indirect potable reuse programs is questionable, as reuse programs in Oklahoma remain unplanned. Additionally, development of indirect non-potable reuse systems is being evaluated under the

Wastewater Master Plan. This strategy is based on supplying reclaimed water for irrigation demands to commercial developments. This program, in general, offers significantly less political, regulatory, and public hurdles, as the systems will be for restricted access sites. However, this system can provide a platform for public education. Additionally, this type of program can provide a first step in developing additional water reclamation programs, as field data from the program will be generated to support additional reclamation expansions. Furthermore, this program can provide potable water conservation.

3.2.7 Long List Summary

For the 40-year planning horizon, several water supply alternatives are potentially available to the City of Norman. Each alternative was characterized based on water quality, location, water storage capacity, available water supply yield, cost associated with securing water supply, policy issues, and likelihood of development. To this end, pertinent information was obtained through discussion or previous reports and studies from the COE, Bureau of Reclamation, OWRB, USGS, Oklahoma Geological Survey, ACOG, COMCD, and the Cities of Oklahoma City, and Norman. For the Strategic Water Supply Plan, a short-list of alternatives for further development was compiled. Each water resource was either short-listed or discounted based on initial evaluation of the following factors.

- Water quality
- Potential yield
- Feasibility of development
- Outstanding policy issues
- City of Norman Strategic Water Supply Policy
- Alternatives identified in the scope for this Strategic Water Plan as being most worthy of further development
- Discussion with City staff and findings in previous reports and studies

Table 3-24 summarizes the characterization of the water resources potentially available to the City of Norman. Table 3-24 also presents a preliminary assessment of the implementation windows required for each water resource alternative. Short-listed alternatives are further developed in Section 3.3.

3.2.8 Terminal Storage Options

Terminal storage can provide multiple uses in a water supply system. Just as the clearwell storage trims the required size of the WTP from maximum-hourly flow to maximum-daily flow requirements, a terminal reservoir trims the size of the raw water conveyance system from maximum-daily flow to average-daily flow requirements. The use of terminal storage

Table 3-24
Summary of Water Resource Alternatives Considered

Water Resource Alternative	Water Quality Required Level of Treatment [a]	Total Estimated Available Yield (mgd)	Estimated Water Resource Cost [a]	Short Listed	Comment
Short-Range (1 to 5 year implementation)					
Additional Lake Thunderbird - Under Utilized COMCD Allocation	Conventional	3 to 5	N/A [b]	*	Conditional Alternative
Additional Lake Thunderbird - Flood Control Pool	Conventional	< 0.1 to 16 (+)	N/A [b]	*	Conditional Alternative
New Garber-Wellington Wellfield	Disinfection Only	10 to 14	N/A [c]	✓	Developed Alternative
Canadian Terrace Deposits	Advanced	see comment	see comment		Discounted - Limited yield, unknown aquifer characterstics, and questionable water quality
Canadian Alluvial Deposits	Advanced	1 to 3	see comment		Discounted - Limited yield, unknown aquifer characterstics, and questionable water quality
OKC Treated Water Purchase (Base Supply)	None	30 (+)	$1.65 / 1,000 gallons	✓	Developed Alternative
OKC Treated Water Purchase (Peak Supply)	None	30 (+)	$2.51/1,000 gallons	✓	Alternative considered for planning horizon as a "contigent" supply source to meet maximum daily demands (as needed).
Direct Nonpotable Reuse	N/A [d]	0.036 (+)	N/A [d]		Potential development is considered under the Wastewater Master Plan.
Medium-Range (5 to 20 year implementation)					
Arbuckle-Simpson Aquifer	Disinfection Only	see comment	see comment		Discounted - Unknown availability, yield, aquifer characterstics,and water quality parameters.
McGee Creek Reservoir	Conventional	10.5	$23 Million		Discounted - Limited interest of McGee Creek Authority to sell storage capacity.
Indirect Potable Reuse	Advanced	10 to 26 (+)	N/A [d]		Policy issues and public acceptance could prevent development.
OKC Raw Water Purchase	Conventional	30 (+)	$0.83 / 1,000 gallons	✓	Developed Alternative
Long-Range (20 to 40 year implementation)					
Sardis Reservoir	Conventional	122	$40 Million		Kiamichi River Basin Development Plan (HCR 1066) would likely limit securing water supply directly from Sardis.
Kiamichi River	Conventional	130	$29,450		Discounted based on limited availibility of firm yield for any given year. Cost prohibitive conveyance / storage infrastructure required w/o partnering.
Hugo Reservoir	Conventional	30 (+)	$3.6 Million	✓	Developed Alternative
New Parker Reservoir	Conventional	41	$80.2 Million		Discounted based on findings of previous studies and scope.
New South Canadian Reservoir	Advanced	30 (+)	see comment	✓	Developed Alternative

Notes:
* Conditional Alternative: indicates an option that is a supplement to a short-listed resource and is not a stand-alone option.
✓Selected Alternative: indicates a short-listed resourse that has been selected for further development independent of other resources.
[a] Cost to secure water resource does not include conveyance and treatment infrastructure capital and O&M costs
[b] Not Applicable - cost for water supply would be attributable to raw water conveyance O&M costs.
[c] Not Applicable - cost for water supply would be attributable to wellfield infrastructure capital and O&M costs.
[d] Not Applicable - water supply is treated effluent from the WWTP. Cost for such supply is attributable to WWTP, conveyance, and WTP capital and O&M costs.
Level of Treatment:
1. Conventional includes clarification, filtration, disinfection with potential for softening.
2. Advanced includes conventional plus ozone/GAC or membranes.

allows the conveyance system to be designed for average-day flows rather than maximum-day flows. This significantly reduces the required capacity of the pipeline and pump station and consequent cost of the raw water conveyance system. Another use of a terminal storage basin is to store diverted raw water during a water resource high-yield period so that adequate supply is maintained to the WTP during low-yield periods. Furthermore, the use of terminal storage is an effective tool for the equalization of raw water quality. For example, the effects of a high turbidity event can be dampened throughout the storage volume.

Currently, the City of Norman uses Lake Thunderbird for its terminal storage reservoir. However, the City's usage is at full allocation. As the 40-Year planning horizon indicates a 30 mgd increase in average flows, Lake Thunderbird will not be able to sustain the required storage volume the Norman WTP will eventually require in order to regulate raw water conveyance flows. Additional terminal storage is required to regulate the flow conveyed from the terminal reservoir to the WTP.

In addition, common to most surface water resource options presented in this report, the need for a terminal reservoir so that raw water may be captured during high-yield periods and stored for use during low-yield periods. Great potential for capturing long-term water resources lies in Southeastern Oklahoma with the Atoka/McGee Creek Reservoirs, Sardis Reservoir, Kiamichi River, Hugo Reservoir, and Parker Reservoir, but storage for these resources is required. The Lake Thunderbird flood control pool and under-utilized COMCD allocation could also benefit the City of Norman with the use of a terminal reservoir. Lastly, the South Canadian River offers a nearby water resource for the City of Norman, but also requires storage. As the need for raw storage has been discovered, two basic terminal reservoir approaches are discussed in the following paragraphs.

East Side Reservoir

A terminal reservoir strategically placed on the east side of the City could store raw water stemming from several resources: Lake Thunderbird, Oklahoma City raw water purchase, Southeast Oklahoma raw water, and South Canadian River raw water.

City staff has discussed the possibility of using Midwest City and Del City's under-utilized allocations with those cities representatives. A potential supply of 3 to 5 mgd is available to Norman, but only as a short-term supply. In addition, the excess floodwater that is currently released from Lake Thunderbird may be captured by the City and stored for future use. As was presented in Section 3.2.2, the City could have captured over 30 mgd in most years by capturing Lake Thunderbird flood control pool raw water.

The South Canadian River, as previously discussed, has an available allocation of 81.7 mgd. However, as evidenced by the number of consecutive days with flow below 10 mgd, raw water storage would be required to develop the South Canadian River as a raw water supply source.

The Atoka/McGee pipeline intersects Lake Thunderbird. Approximately 10 mgd of additional conveyance is available in the pipeline without expansion improvements to the pumps or associated equipment. Water supply from the conveyance pipeline could be released into a new terminal reservoir and then transferred to Norman's WTP for treatment prior to distribution.

Finally, there has been interest in developing water supply from the Kiamichi River Basin by Central Oklahoma communities. Norman, Oklahoma City, Edmond, Moore, Yukon, Piedmont, Purcell, ACOG, and OWRB have all been active in discussing the potential for developing water resources in Southeast Oklahoma. Development of conveyance infrastructure will be a major factor for transferring water supply from the Kiamichi River Basin to Central Oklahoma. Considering the capital investment and annual O&M costs for such infrastructure, it is reasonable to assume that OKC or other Central Oklahoma communities would be interested in developing a partnership for implementation of water supply from the Kiamichi River Basin. A terminal reservoir in proximity to the WTP would provide the City with flexibility and leverage to develop this partnership.

Finally, the east side reservoir would decrease the required size of the raw water conveyance system, both pumps and lines sizes, extending from the reservoir to the WTP. Rather than the system conveying the maximum-daily flow, it would be required to convey only the average-daily flow. This would provide for a significant reduction in costs of the raw water conveyance system.

West Side Reservoir

Applicable only to capturing water from the South Canadian River basin is the option of an additional terminal reservoir located on the west side of Norman. As the South Canadian River flows along the west edge of Norman, providing conveyance requirements from the river to the east side of Norman would be costly. Hence, a west side reservoir would decrease the size of pumps and pressure line maintenance required and the raw water could potentially flow by gravity from the west side to the east side reservoir.

In addition, as presented in Section 3.2.4, South Canadian River raw water quality has been characterized as less than high quality. Pumping such raw water directly to an east side reservoir would compromise the quality of the other water resources being stored in the reservoir. However, a west side reservoir could act as a primary settling basin for the raw river water and potentially improve the quality prior to treatment. This would effectively reduce treatment costs. This will be considered subsequently with development of the South Canadian River Alternative.

3.3 Short List (Water Resources) Development

3.3.1 General

Seventeen water resource alternatives were evaluated in Section 3.2 as potential components for the Strategic Water Supply Plan. Results from that evaluation recommend the following six water resource alternatives for further development as potential components of the Strategic Water Supply Plan.

1. Additional Garber-Wellington Aquifer Yield
2. Additional Lake Thunderbird Yield
3. South Canadian River
4. Oklahoma City Treated
5. Oklahoma City Raw (Southeast Oklahoma)
6. Hugo Reservoir (Southeast Oklahoma)

Infrastructure needs required for implementation of each of the short-listed water resource alternatives is identified as follows.

3.3.2 Additional Garber-Wellington Aquifer Yield

As discussed, additional yield from the GWA is available to the City of Norman. For water quality reasons and sustainability of the aquifer, it has been recommended that all future development be in nrtheast Norman, between the outcrop of the Henessey Shale and Lake Thunderbird. Both water quality and wellhead yield are expected to improve in this portion of the aquifer. A conservative groundwater development approach is recommended herein to prevent over-production (i.e., mining) of the aquifer.

Expanded Wellfield Development Plan

Based on existing information on the aquifer and the recommendation of the Garber-Wellington Association, four primary well alignments are recommended for development within the unconfined portion of the aquifer. The suggested alignments are conservatively spaced with separations of about two miles. As the aquifer is developed and hydrogeologic studies are completed, the potential may exist to "fill" additional wells mid-way between the alignments. This configuration will also accommodate a common wellfield collection pipeline that can route the additional groundwater production to a common disinfection facility prior to distribution. The recommended development plan is described below and illustrated on Figure 3-9.

The City has recently completed six new production wells to the west of the proposed wellfield. The following general aquifer testing procedure is recommended, using these wells and an observation well. First, each well should be tested individually. All nearby wells should be turned off to allow groundwater levels to stabilize. A pressure transducer would then placed in the test well to collect at least 12 hours of water-level background data. The well pump should be started while monitoring the pump discharge rate (should be constant at the desired use rate). The well should be pumped for 72 hours or until the water level stabilizes while the pressure transducer system records changes. This same test procedure should be used on each new well.

Following completion of individual wells testing, additional multi-well testing should be conducted. A pressure-transducer system or a water-level recorder should be installed on a monitoring well located within 500 feet of one of the production wells. All pumping from production wells located within 1-1/2-miles of the monitoring well should be terminated for a period of 24 hours. Water levels should be recorded in the monitoring well for a period of 24 hours after cessation of pumping to obtain background data. A pressure transducer should be installed in the production well closest to the monitoring well and the two other production wells, if possible. Then, the production well pump should be started and run at a constant rate for a period of 5 to 10 days. The water level changes in the monitoring well and the distant production wells should then be recorded using the transducer system. Also,

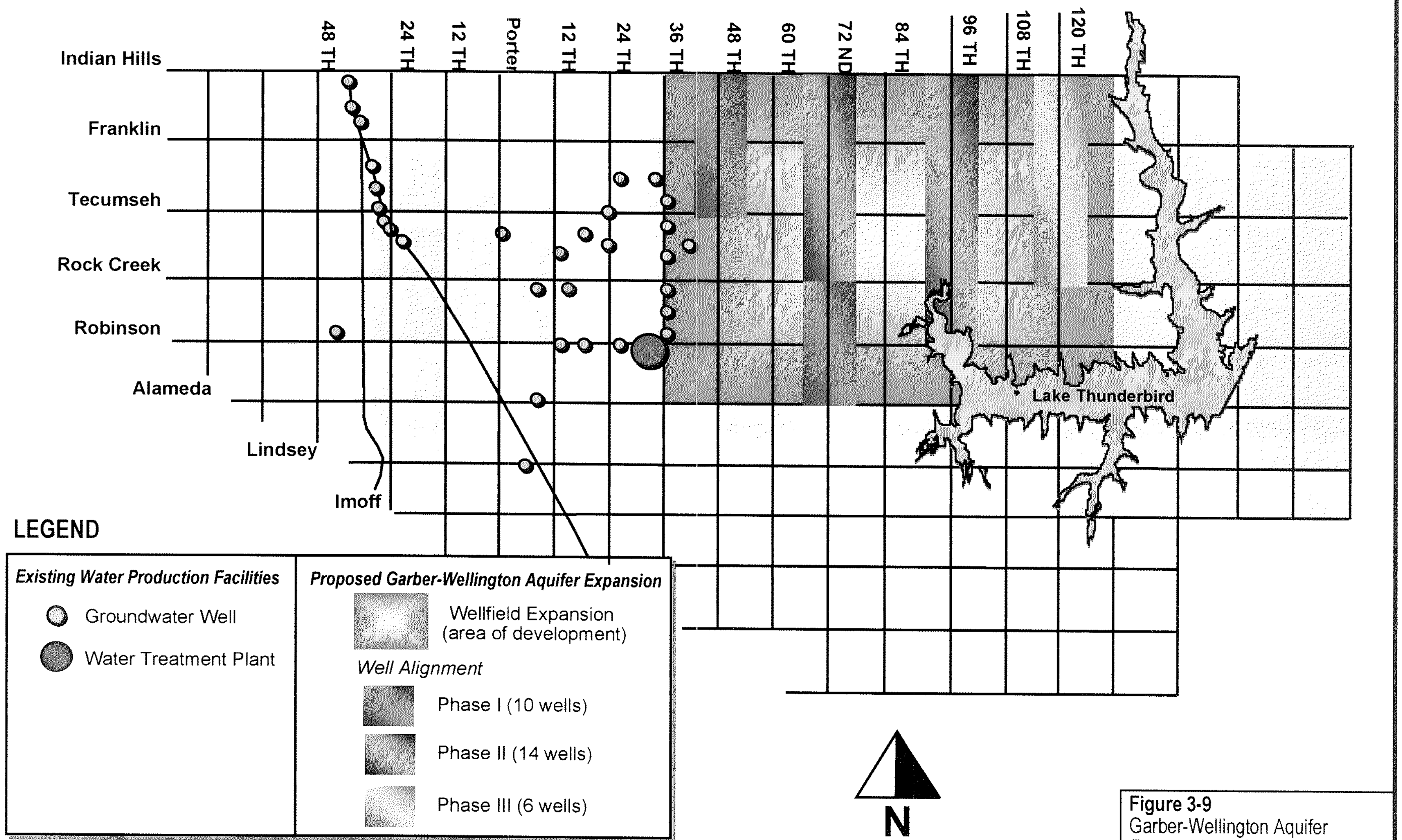


Figure 3-9
Garber-Wellington Aquifer
Proposed Wellfield Expansion

the pumping rate should be monitored. Upon completion of the test, the production well should be turned off and the recovery data recorded for a period of about 72 hours.

An analysis of the hydraulic data generated by the described testing will help verify the feasibility of the aquifer development plan for the GWA. It is advised that this investigation be conducted prior to purchase of additional well sites and rights-of-way for piping.

Phase I—10 New Wells. Phase I development includes construction of 10 production wells with 5 wells being located in a north-south alignment along East 48th/Douglas and 5 wells in the southern part of the development area along East 72nd/Westminister. These two alignments are offset to minimize drawdowns in the event that the testing indicates a potential problem. Based on an assumed transmissivity of 3,000 gpd/ft, a specific yield of 0.02, a pumping rate at each well of 350 gpm, and a stress period of 120 days, the estimated drawdown of water levels in the production wells would be as much as 237 feet. This drawdown estimate is based on a simplified analytical model.

Hydrogeologic testing is recommended at the middle of each alignment prior to construction of any production wells. The middle production well should be drilled using the following procedure.

1) Drill a pilot hole to approximately 600 to 700 feet in total depth (drill cutting should be collected for analysis).
2) Perform geophysical logs on the well to determine the location of sandstones that have acceptable yield characteristics.
3) Design the well based on the geologic analysis to place high-quality wire-wound screens in the appropriate sandstone intervals.
4) Use a non-metallic casing and 316L stainless-steel screens to maximize well yields.
5) Grain pack the screen intervals with appropriately sized gravel to maximize flow through the yields.
6) Design the final pumping system to achieve a flow velocity of no greater than 0.1 ft/sec through the screens.
7) Develop the well using a combination of compressed air lift and water jetting to clean and stratify the gravel pack.
8) Conduct a 5- to 6-hour step-drawdown test to evaluate the screen efficiency well yield.

A monitoring well should be constructed using the identical screened intervals as the production well. The monitoring well should be located no more than 500 feet from the production well. A second monitoring well should be constructed beside the deep monitoring well. It should tap the upper part of the unconfined aquifer.

Upon completion of the production well and the monitoring wells, an aquifer performance test should be conducted. The monitoring wells and production well should be equipped with pressure transducers for continuous measurement of water level changes in the aquifer before, during, and after the pumping period. At least 24 hours of background water level data should be collected prior to initiating the pumping test. The pump should be started and a constant pumping rate should be maintained for a period of 10 days. The pressure transducer system should be used to measure water levels during the pumping period and for at least 3 days after pumping is terminated.

After completion of the testing, the aquifer hydraulic coefficients should be calculated. These coefficients and locally collected geologic information should be used to model the proposed Phase I well withdrawals to assess if the development plan design will be productive, and to assess drawdowns in individual production wells.

If the results of the hydrogeologic analysis are positive, then the 10 wells should be constructed. Each production well should be constructed and tested in the same manner as described for the first well. As part of the overall wellfield construction plan, at least three additional permanent monitoring wells should be constructed in and around the wellfield. The final location of these monitoring wells will be determined through modeling and testing results. Permanent water-level recorders should be installed on each monitoring well to assess changes in aquifer water levels. Water samples should be collected from the production wells on a regular basis for chemical analysis to comply with drinking water standards.

Phase II—14 New Wells. The recommended Phase II development involves the construction of six production wells located north of the Phase I alignment along East 72nd/ Westminister and eight production wells in a north-south alignment along East 96th/ Hiwassee. Based on a very preliminary analytical model using a transmissivity of 3,000 gpd/ft, a specific yield of 0.02, a pumping rate at each well of 350 gpm, and a stress period of 120 days, the maximum drawdown in the production wells should be about 237 feet. This is nearly the same as the expected drawdown for the first alignment.

It is recommended that the same development program be used for Phase II as was detailed for Phase I. An aquifer performance test should be conducted in the center of each potential alignment and the appropriate modeling should be completed. It is probable that the same computer model could be used for all phases; and each time new data are collected, the model could be updated and improved.

Phase III—6 New Wells. Phase III wellfield development involves the construction of six production wells in a north-south alignment to the east of Phase II along East 120th/ Choctaw. A preliminary model of this alignment using the same hydraulic parameters and stress period as the other phases yields a drawdown of 237 feet in each production well. These alignments and pumping rates were chosen to minimize well interference.

The same general hydrogeologic test program as previously described should be conducted at the Phase III location. Cost savings could exist if the testing program for all phases was consolidated into a single test program and modeling effort. If the test procedure is phased with the wellfield development, the cost would be spread over the timeframe for full wellfield development. If the consolidated hydrogeologic testing and modeling program is conducted prior to the implementation of construction, there would be greater certainty in the overall yields of the system and the feasibility of the plan.

Recommendations

Preliminary aquifer analysis suggests that operation of the 30 new wells could yield an annual average of approximately 10 mgd. This could be achieved using 70 percent of the wells at one time. This allows for alternating wells to allow the aquifer to stabilize in certain areas. Use of all 30 wells for short durations could yield approximately 14 mgd to meet peak demands. However, the yield could be less or greater depending on the reaction of the aquifer. It will be very important to assess the possible impacts to the recharge of the existing wellfield, as well as the surficial part of the aquifer to be sure that stream flows are not adversely affected or that vertical drainage to the aquifer is coming from Lake Thunderbird. As such, it is not recommended to count on additional water supplies, above that stated herein, from the GWA without long-term (10 years) water-level and quality monitoring to assess the aquifer reaction to the recommended new wellfield.

Development of the aquifer in this way will not only provide a reliable supply to the City, but it will also protect the integrity of the aquifer by decreasing the likelihood of salt water intrusion, which leads to poorer water quality. Due to the low cost of this alternative relative to others and the ease and implementation to gain a good water resource, this option will continue to be developed for the Strategic Water Supply Plan.

3.3.3 Additional Lake Thunderbird Yield

Options for obtaining additional yield from Lake Thunderbird include using lake flood pool storage and unused COMCD allocations to Midwest City and Del City, realizing these options hinge on the ability to capture and store water during periods of high watershed yield. This alternative will require a new terminal reservoir and likely upgrades to the existing raw water conveyance system. Although no additional water rights are available, these options are considered conditional water resource alternatives with the potential for additional Lake Thunderbird yield.

An east side terminal reservoir, located between Lake Thunderbird and the WTP, adjacent to the raw water pipeline has the potential to serve all identified short-list surface water resource alternatives. Consideration is discussed in the following paragraphs relative to operating volume and potential siting options. Notably, terminal storage needs relative to implementation of the South Canadian River alternative are discussed in Section 3.3.4.

Terminal Storage Volume Options

To ascertain available surplus supply from the Lake Thunderbird watershed, historic flow data was adopted from USGS Gauging Station No. 07230000, located on the Little River just downstream of the Norman Dam. Data from 1979 through 1999 were available from the USGS. Daily flows were adjusted to account for existing water rights (40 ac-ft per year) and base flow conditions.

Diversion with Existing Conveyance Capacity. One scenario for capturing the available flow from flood pool releases would be utilization of the existing Lake Thunderbird raw-water conveyance infrastructure. To this end, capacity of the existing infrastructure not used to transfer needed supply to the WTP could be used to divert supply from the flood-control pool to a terminal storage reservoir when flood control releases occurred. As discussed in Section 3.2.2, daily river flows of the Little River and WTP daily production records from

1990 through 1998 were used to evaluate this scenario. Although additional supply could be gained, the amount on an annual-average basis was limited. The annual-average supply from capturing flood releases from Lake Thunderbird utilizing the existing raw-water conveyance system ranged from 0.7 to 4.1 mgd. Monthly diversion averages (when flood control releases occurred) over any given year in the historic data set ranged from 0.2 to 8 mgd. As such, the maximum-monthly operational storage volume required to realize this scenario would be less than 250 MG.

Diversion with Expanded Conveyance Capacity. Another potential scenario for capturing water supply from the Lake Thunderbird flood-control pool includes expanding the raw-water conveyance system capacity by 10 mgd to divert such supply. Daily river flows from 1979 through 1999 were evaluated to identify when flood-control releases occurred. Based on a 20-year average, this supply scenario could yield 2.3 mgd on an annual-average basis. However, annual-average yield for any given year ranged from zero-mgd to 4.9-mgd. During 1981, the Little River annual-average daily flow downstream of the Norman Dam was only 0.27 mgd, which indicates no flood-control releases from the lake during that year. Hence, no additional water supply could be captured for that year. Noteworthy, current management of the flood control pool has changed from operations prior to 1986. This change in flood control pool management is attributable to construction that raised the elevation of the Twin Bridge in 1986. In any event, the average-annual yield that could be captured from Lake Thunderbird during flood-control releases, assuming a diversion rate of 10 mgd, would have been less than 1 mgd in 1994. Table 3-25 summarizes this analysis.

TABLE 3-25
Lake Thunderbird
Surplus Water Diversion and Yield

		Raw Water Diversion from Flood Control Pool			
Year	Total Days	No. of Days	Volume (MG)	Avg. Rate (mgd)	Annual Avg. Supply (mgd)
1979	31	0	0	0	0.0
1980	366	26	260	10	0.7
1981	365	0	0	0	0.0
1982	365	43	430	10	1.2
1983	365	121	1210	10	3.3
1984	366	54	540	10	1.5
1985	365	179	1790	10	4.9
1986[a]	365	118	1176	10	3.2
1987	365	93	924	10	2.5
1988	366	57	570	10	1.6
1989	365	81	810	10	2.2
1990	365	104	1029	10	2.8

TABLE 3-25
Lake Thunderbird
Surplus Water Diversion and Yield

Year	Total Days	Raw Water Diversion from Flood Control Pool			
		No. of Days	Volume (MG)	Avg. Rate (mgd)	Annual Avg. Supply (mgd)
1991	365	81	793	10	2.2
1992	366	177	1780	10	4.9
1993	365	135	1343	10	3.7
1994	365	30	300	10	0.8
1995	365	87	870	10	2.4
1996	366	57	561	10	1.5
1997	365	82	820	10	2.2
1998	365	86	860	10	2.4
1999	273	81	798	10	2.9
20-Year Avg.		**85**	**850**	**10**	**2.3**

Note:
Elevation of Tin Bridge raised.

Based on the 20-year annual average for this flood-control pool scenario, a terminal reservoir with an annual operational volume of 850 MG would realize 2.3 mgd in additional annual-average yield. Implementation of additional terminal storage volume under this scenario would not be supported during low-yield years. Although, with diversion provisions in place, under-utilized COMCD water supply from Lake Thunderbird could be diverted to the terminal reservoir for reservoir pool-level maintenance, as needed and when such supply is available. The availability of this potential increase in annual-average yield could be limited in any given year. As discussed, water supply from Midwest City and/or Del City allocations is available. However, such supply is unreliable as neither municipality expressed an interest in relinquishing water rights. Nevertheless, supply from Lake Thunderbird can be captured from the flood-control pool and/or COMCD conservation pool, when available, and stored in a terminal reservoir.

Lake Thunderbird Augmentation. As discussed in Section 3.2.4, a great potential for capturing long-term reliable water resources lies in Southeastern Oklahoma with the Atoka Reservoir, McGee Creek Reservoir, Sardis Reservoir, Kiamichi River, Hugo Reservoir, and planned Parker Reservoir. A likely possibility for utilization of any one or combination of these alternatives would include routing through Lake Thunderbird. Although Lake Thunderbird has sufficient volume for routing, it does not have available storage to accommodate the City of Norman's long-term terminal storage needs. A new terminal reservoir would be effective for storing the augmented Lake Thunderbird flows and subsequent conveyance to the City's WTP. This considered, the terminal reservoir storage volume requirement must be evaluated for the Lake Thunderbird augmentation scenario.

For this scenario, a water-demand based approach for terminal storage volume sizing was assumed. The primary purpose for terminal storage volume is to trim the difference between maximum-day production and resource annual-average yield during high-water demand periods. This is common practice in water supply management for resource protection and minimization of necessary conveyance infrastructure. Assuming a surface water resource and raw water conveyance system are providing annual-average flow to a WTP, a terminal reservoir would be utilized to supply the differential between maximum-day and annual-average production for high-demand summer months. Conversely, the terminal reservoir would be filled during low-demand months. The raw water conveyance system would continue to provide annual-average flow; however, flow not required by the WTP would be diverted to the terminal reservoir.

Considering water production projections developed in Section 1, Baseline Development, discounted for planned groundwater production, a 3,200 ac-ft (or 1.05 BG) terminal storage volume would effectively supply the WTP with sufficient flow to meet projected maximum-day demand for the following sustained durations.

- Year 2000: 4 months
- Year 2020: 2.5 months
- Year 2040: 1.5 months

Such operational volume would satisfy the 30-day-target minimum-duration criteria for Year 2040 with conservation volume for water quality and aesthetics management. Notably, an expansion in capacity will be required to the City's existing raw water conveyance system to realize this Lake Thunderbird augmentation scenario.

Terminal Storage Siting Options

For the purpose of realizing additional yield from Lake Thunderbird, the location for a new terminal reservoir (Lake Campbell) is recommended to be adjacent to the existing raw water conveyance system. This is advised to minimize additional piping requirements for filling and drawing the reservoir. An ideal site would have sufficient natural topography relief to realize a median-depth sufficient for water-quality management and surface area control. Evaluation of possible sites has led to the identification of two possible locations for the new Lake Campbell.

Rock Creek West Branch (WTP) Option. For ease of implementation and future operations, siting of a terminal reservoir is typically adjacent to the WTP to be served when land use permits. In the case of the City, an ideal site exists adjacent to the WTP for development of Lake Campbell.

The western branch of upper Rock Creek flows immediately south and east of the existing WTP. A detailed digital terrain analysis was performed to determine the storage potential of a terminal reservoir on this branch. An alternative was analyzed using natural topography only. Another alternative was analyzed assuming some topographic contour shaping to increase storage while controlling surface area. Results of this analysis are reported in Table 3-26.

TABLE 3-26
Lake Campbell - Rock Creek West Branch Storage Analysis

Water Surface Elevation	Volume (cf)	Volume (ac-ft)	Volume (MG)	Water Surface Area (sf)	Water Surface Area (ac)	Water Surface Perimeter (ft)	Water Surface Perimeter (mi)
Alternative A – Natural Topography							
1150	200,568,424	4,604	1,505	13,584,307	312	34,999	6.63
1145	146,016,594	3,352	1,095	9,934,947	228	25,466	4.82
1140	101,094,797	2,321	758	8,027,101	184	24,566	4.65
1135	69,084,137	1,586	518	5,810,734	133	15,771	2.99
1130	42,955,227	986	322	4,620,532	106	15,354	2.91
Alternative B – Reshaped Topography							
1150	253,883,624	5,828	1,905	17,956,951	412	31,265	5.92
1145	149,686,303	3,436	1,123	15,132,744	347	28,830	5.46
1140	102,764,037	2,359	771	12,846,988	295	27,900	5.28
1135	69,458,998	1,595	521	5,977,656	137	15,539	2.94
1130	42,955,227	986	322	4,620,532	106	15,354	2.91
Alternate B versus Alternate A Earthwork							
Excavation (CY) equals 4,558,845							

As indicated, the west branch storage analysis reveals that impoundment of the USGS datum 1145 contour would provide sufficient storage volume to satisfy the 3,200 ac-ft (or 1.05 BG) requirement for the Lake Thunderbird augmentation scenario discussed previously. Such an impoundment would require a dam along 36th at the confluence of the western branch to Rock Creek. Land area required for development of this site is assumed to be approximately 320 acres.

Although the Rock Creek West Branch site is ideal and volume analyses results are encouraging, recent upper-scale residential housing has been constructed on large tracts in the target area that may render this site unsuitable for development as a terminal reservoir. As such, another site alternative has been identified for potential development of Lake Campbell.

Falls Creek South Branch Option. Another potential site for terminal reservoir development has been identified along 72nd just south of the existing raw water conveyance system and north of Alameda. A dam along 72nd would impound the USGS 1,150 datum contour of the south branch of upper Falls Creek. Conceptual development of this option is provided in Table 3-27.

TABLE 3-27
Lake Campbell – Upper Falls Creek Conceptual Development

Parameter	Quantity
Anticipated Land Area	200 acres
Natural Contour Boundary (elevation)	1,100 to 1,150 ft
Surface Area	160 acres
Total Storage	3,200 acre-ft
Average Depth	20 ft

This site offers considerably more natural vertical relief than the Rock Creek option. As such, it is apparent that a greater reservoir effective depth would be realized. The increased depth would yield a land area economy relative to the Rock Creek option. This economy would help offset the additional fill and withdrawal infrastructure costs relative to the Rock Creek option. Nevertheless, located approximately 4 miles east of the WTP and 1/2-mile south of the raw water pipeline, this site would satisfy the objectives of the terminal reservoir locations discussed. Infrastructure required for implementation of Lake Campbell includes a fill tee off the raw water line, a 42-in fill pipeline to the reservoir, a diversion inlet at the reservoir, a 44-mgd pump station at the reservoir, a 42-in withdraw pipeline return, and a return tee on the raw water line. Conceptual costs for development of Lake Campbell are provided in Table 3-28.

TABLE 3-28
Lake Campbell - Development Costs

Item	Quantity	Unit Cost	Total
Land Acquisition	200 acres	$4,000	$800,000
Reservoir Construction	3,200 ac-ft	$1,200	$3,840,000
Inlet Structure	44 mgd	LS	$234,000
Pump Station	44 mgd	LS	$1,452,000
Fill / Withdrawal Pipelines	42-in	LS	$1,716,000
Electrical / I&C	--	LS	$320,000
Utility Relocation	--	LS	$280,000
Subtotal			$8,642,000
Contingency (35%)			$3,022,000
Total			**$11,664,000**

Raw Water Conveyance

As previously discussed, Lake Thunderbird has sufficient capacity to allow augmentation with additional source(s) of water supply. Under such development scenarios, Lake Thunderbird would serve as an intermediate terminal reservoir for these water supplies. Following conveyance or delivery to Lake Thunderbird, water would be withdrawn from the Lake and conveyed to the new terminal reservoir or the WTP.

As developed, the new terminal reservoir storage capacity would be sized for the difference between annual-average WTP production and maximum-rated capacity of the WTP. This could reduce conveyance infrastructure capacity from Lake Thunderbird to the new terminal reservoir, as infrastructure would be based on annual-average WTP production in lieu of peak production. However, development of the new raw water conveyance system will be sized for maximum capacity of the WTP for the following reasons. Implementation of a terminal reservoir for the sole purpose of minimizing conveyance infrastructure from Lake Thunderbird to the WTP has limited potential. In short, cost savings in required conveyance infrastructure could not recover the capital and O&M costs associated with the new terminal reservoir. Simply, the length of run is not great enough to realize the economy. Additionally, issues such as potential degradation of water quality in the terminal reservoir must be considered. A common phenomenon associated with shallow terminal reservoirs in Central Oklahoma is algae blooms, as sunlight can penetrate through the entire water column. Additionally, shallow terminal reservoirs are prone to stratification. Furthermore, processing stagnant water typically results in greater physical and/or chemical treatment needs at the WTP and can lead to objectionable tastes and odors in the finished water. As such, a raw water conveyance system sized for WTP capacity will facilitate greater operational flexibility and throughput at the terminal reservoir.

Currently, raw water from Lake Thunderbird is transferred to the WTP through a conveyance system, which is owned and operated by COMCD. As discussed in Section 2, the rated design capacity of the conveyance system at Lake Thunderbird is 14 mgd. Expansion of the raw water conveyance system would be needed to support increased WTP production capacity. To this end, a raw water conveyance expansion component is developed herein to convey water from Lake Thunderbird to the WTP for the Year 2040 WTP buildout capacity of 44 mgd. Table 3-29 presents the Year 2040 buildout WTP raw water conveyance alternative and planning criteria.

Recommendations

Notably, the existing raw water conveyance system is owned and operated by COMCD. It is reasonable to assume that plans to expand the existing system capacity from 14 mgd to 44 mgd must include COMCD. If so, it is conceivable that the City of Norman would be required to fund only 43.8 percent of the raw water system improvements. Furthermore, the City may be able to gain financial assistance from COMCD and/or the Bureau of Reclamation for implementation of the new terminal reservoir. In the event either possibility becomes reality, the Additional Lake Thunderbird Yield water resource alternative would be even more attractive. Considering the identified short-list water resource alternatives to be developed in the following sections, all but the contract purchase of treated water from OKC will require the implementation of an east side terminal reservoir.

TABLE 3-29
Proposed Year 2040 WTP Raw Water Conveyance System

Capacity Component		Capacity	Planning Criteria
WTP Capacity		44 mgd	Proposed 2040 build out capacity
WTP Raw Water Conveyance Capacity		44 mgd	Required conveyance capacity
Cost Component	**Number of Units**	**Estimated Capital Cost [b] (x $1,000)**	**Planning Criteria**
Piping	See note [a]	7,155	7 ft/s flow velocity
Pump/Motor	4	1,100	WTP 2040 buildout capacity
Subtotal		$8,255	
Contingency (20%)		1,651	
Total		**$9,906**	

Notes:
[a] 42,590 ft of 42-inch diameter piping.
[b] Potential right-of-way, easement, and land acquisition costs not included.

3.3.4 South Canadian River

Other Central Oklahoma municipalities, such as OKC, are showing an interest in developing the South Canadian River as a water supply source. For the City, the greatest potential for development of the South Canadian River as a water supply resource would be associated with capturing a water supply that has limited availability over the course of a year. With the implementation of adequate storage, the South Canadian River could be developed into a viable source of water supply.

Raw Water Diversion/Conveyance

As previously discussed, a South Canadian River raw water supply system would likely divert flow near Norman. Timing and duration for diverting water supply from the South Canadian River is dependent on river flows. In return, such diversion events will govern the quantity of water that can be captured.

To evaluate potential water supply diversion practices, 1979 through 1999 daily mean river flow data were adopted from the USGS gauging station at Purcell, Oklahoma. As shown previously, available data for a 20-year historic record from this gauging station includes water years 1979 through 1983 and 1985 through 1999. Daily flows recorded at the gauging station near Purcell were adjusted to define baseline conditions. The river flows were adjusted to account for:

- Existing water right permits and uses;
- 5-year average discharge flows from facilities; and
- Downstream 7Q2 discharge permit criteria.

In general, the South Canadian River has higher total flows at Purcell as compared to Bridgeport, due to a larger drainage basin. Figure 3-10 compares annual-average river flows at the gauging station near Bridgeport and the adjusted-river flows at the gauging station near Purcell. Although the South Canadian River has greater flows at the downstream location (Purcell), both stations demonstrate similar flow patterns.

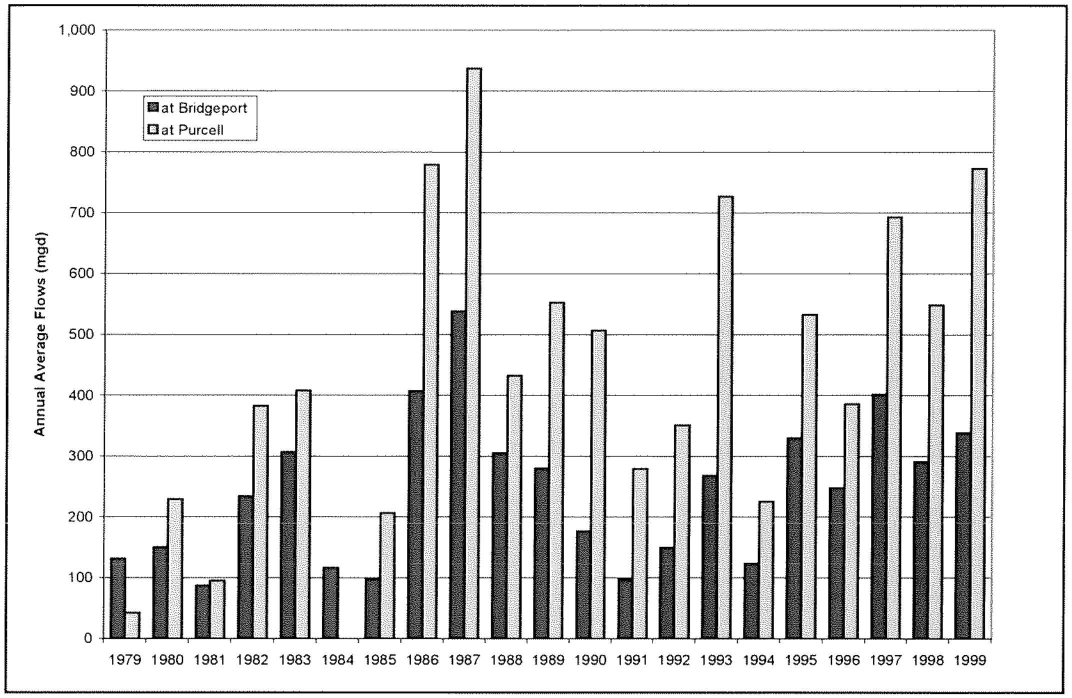


FIGURE 3-10
South Canadian River Flows
Annual Average Flows at Bridgeport Versus Purcell

To adjust for daily-river flow variability in light of raw water system facility capacity and operation, the following potential diversion conditions were assumed.

- Diversion would only occur when the river flow is greater than 100 cfs (64.6 mgd).
- Diversion would be initiated only if the raw water supply could be captured during 10 or more consecutive days.
- Diversion rate and duration would be limited so as not to lower the river flow to less than 100 cfs (64.6 mgd).

One diversion practice scenario considered for developing the South Canadian River evaluated diverting from 5 to 40 mgd (depending on river conditions) during events that satisfied the baseline conditions discussed previously. Table 3-30 summarizes this potential diversion practice scenario and results.

TABLE 3-30
South Canadian River Raw Water Supply
Diversion Practice Scenario No. 1

Year	River Flow (totals)			Diversion Scenario No. 1 (5 to 40 mgd)			
	No. of Days	Volume (MG)	Annual Avg. Flow (mgd)	No. of days	Volume (MG)	Avg. Rate (mgd)	Annual Avg. Supply (mgd)
1979	92	7,730	84	41	935	23	10
1980	366	97,664	267	182	6,465	36	18
1981	365	48,935	134	103	3,100	30	8
1982	365	157,949	433	188	6,660	35	18
1983	273	127,324	466	192	7,390	38	27
1985	92	24,930	271	82	3,125	38	34
1986	365	307,116	841	296	10,940	37	30
1987	365	365,631	1,002	365	13,430	37	37
1988	366	180,329	493	287	10,485	37	29
1989	365	225,178	617	359	14,245	40	39
1990	365	207,423	568	302	11,065	37	30
1991	365	123,116	337	286	10,725	38	29
1992	366	152,041	415	336	13,185	39	36
1993	365	288,745	791	325	11,865	37	33
1994	365	102,733	281	233	9,260	40	25
1995	365	217,363	596	337	12,440	37	34
1996	366	164,574	450	349	13,625	39	37
1997	365	276,520	758	362	14,325	40	39
1998	365	219,838	602	238	9,385	39	26
1999	273	227,121	832	218	8,235	38	30
20-year Summary	6,574	3,522,262	536	5,081	190,885	38	29

Considering implementation of a raw water supply system with a diversion capacity of 40 mgd, development of the South Canadian River could result in approximately 29 mgd of annual-average raw water supply source for the City, based on a 20-year average. The 20-year historic record shows such a diversion practice would result in only an 8-mgd supply in one of the years and approximately 18 mgd in two of the years. Thus, development of the South Canadian River including diversion infrastructure with a 40-mgd capacity would result in a reliable raw water source yielding an annual-average supply of 8 mgd. To potentially increase the annual-average supply captured from the river, scenarios that considered diversion capacities of 50 and 60 mgd were evaluated under the same diversion conditions. Table 3-31 summarizes the results of these two scenarios.

TABLE 3-31
South Canadian River Raw Water Supply
Diversion Practice Scenario Nos. 2 and 3

Year	Diversion Scenario No. 2 (5 to 50 mgd)				Diversion Scenario No. 3 (5 to 60 mgd)			
	No. of days	Volume (MG)	Average Rate (mgd)	Annual Avg. Supply (mgd)	No. of days	Volume (MG)	Avg. Rate (mgd)	Annual Avg. Supply (mgd)
1979	41	935	23	10	41	935	23	10
1980	182	7,865	43	21	182	9,195	51	25
1981	103	3,660	36	10	103	4,140	40	11
1982	188	8,030	43	22	188	9,390	50	26
1983	192	9,090	47	33	192	10,790	56	40
1985	82	3,825	47	42	82	4,495	55	49
1986	296	13,450	45	37	296	15,950	54	44
1987	365	16,450	45	45	365	19,420	53	53
1988	287	12,935	45	35	287	15,225	53	42
1989	359	17,705	49	49	359	20,915	58	57
1990	302	13,595	45	37	302	15,965	53	44
1991	286	12,955	45	35	286	14,825	52	41
1992	336	16,315	49	45	336	19,405	58	53
1993	325	14,465	45	40	325	16,915	52	46
1994	233	11,490	49	31	233	13,670	59	37
1995	337	15,050	45	41	337	17,570	52	48
1996	349	16,895	48	46	349	20,095	58	55
1997	362	17,775	49	49	362	21,195	59	58
1998	238	11,565	49	32	238	13,735	58	38
1999	218	10,315	47	38	218	12,345	57	45
20-year Summary	5,081	234,365	46	36	5,081	276,175	54	42

Figure 3-11 graphically compares Diversion Scenario Nos. 1, 2, and 3 (Tables 3-30 and 3-31) for the two years resulting in the lowest annual-average supply (1980 and 1981). Although additional yield could be realized by implementing water diversion infrastructure with larger capacities, there is a diminishing return on the infrastructure investment. Using 1981 data as an example, increasing the diversion infrastructure capacity from 40 to 50 mgd (25 percent increase in capacity) would result in an 18 percent increase in annual-average supply (8.5 to 10 mgd). With this in mind, there would be over 70 percent return on the additional infrastructure capacity investment. On the other hand, increasing the diversion infrastructure capacity from 40 to 60 mgd (50 percent increase) would result in a 29 percent increase in annual-average supply (8.5 to 11 mgd), or a 58 percent return on additional infrastructure capacity. Considering incremental increases in diversion infrastructure capacity, the increase in annual-average yield realized from increasing the diversion infrastructure from 50 to 60 mgd (20 percent increase) would be 10 percent, or only half the infrastructure capacity investment. Figure 3-12 illustrates the diminishing return on increasing diversion infrastructure capacity.

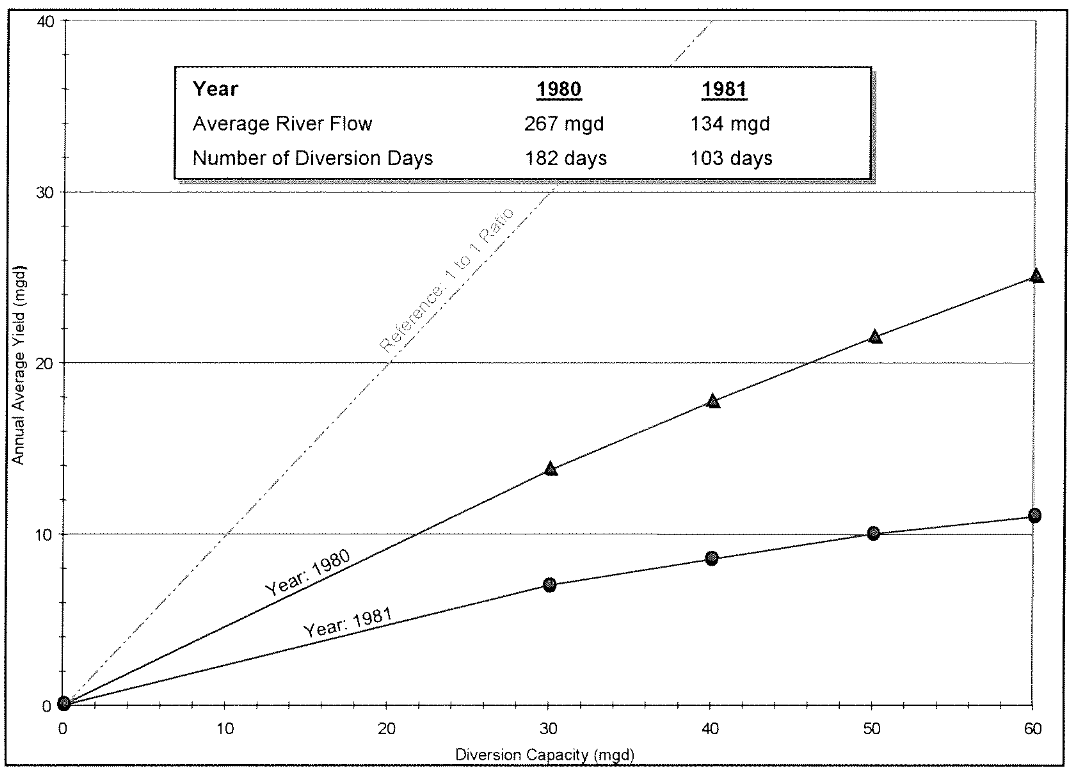


FIGURE 3-11
South Canadian River
Raw Water Diversion Scenarios

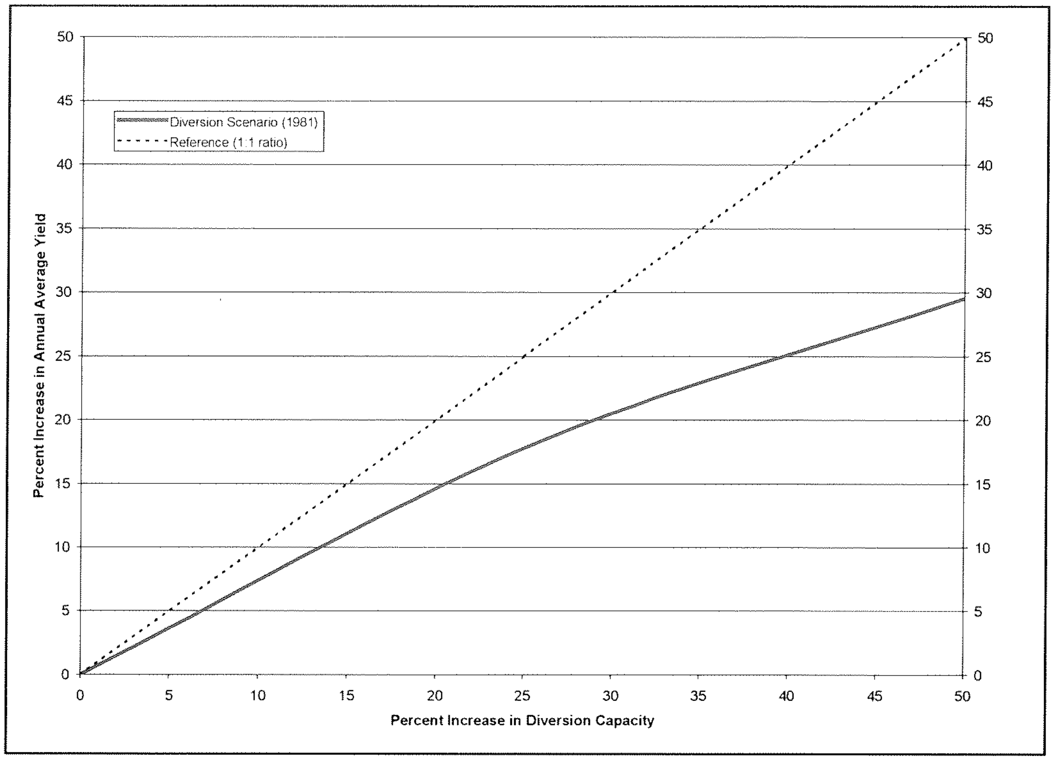


FIGURE 3-12
South Canadian River
Diversion Capacity Vs Water Supply Annual Yield

Development of the South Canadian River under this water supply plan considers implementation of diversion infrastructure with a 50-mgd capacity. Annual-average yields greater than 10 mgd are considered too unreliable for water supply and infrastructure planning for a 40-year horizon. As shown previously, the City could, at times, realize greater than 30-mgd annual-average yield from the South Canadian River through implementing such diversion infrastructure. This annual-average yield exceeds the projected water demand needs over the 40-year planning horizon. Water treatment/ production facility peaking capacity could be implemented to utilize a portion of this additional yield, when available, in meeting daily water consumption needs. This additional capacity would also provide the City with raw water system redundancy.

Water diversion facilities for the South Canadian River could include both subsurface and surface intake structures. The South Canadian River is a "losing and receiving" stream. As such, water flows in the subsurface parallel with the river. Thus, a surface intake structure could be implemented to capture surface flows, especially during periods of significant river flow. Conversely, the subsurface intake structure could be used to capture subsurface flow or capture river flows during low-flow conditions. Such a subsurface intake structure could be a Ranney-type radial well, with horizontal collectors running out from the well to increase percolation from the river. Because the radial well could collect subsurface flows, this type of configuration would increase the yield reliability from the South Canadian River.

Raw Water Storage Needs

Water Quality Basis. Sample windows depicting daily river flows and TDS concentrations are provided on Figure 3-13. As shown, poor water quality has occurred at varying times and at varying river flows. Table 3-32 summarizes water quality with respect to seasonal flow patterns of the South Canadian River. Based on this data, there is not a clear seasonal diversion window for capturing relatively significant changes in water quality.

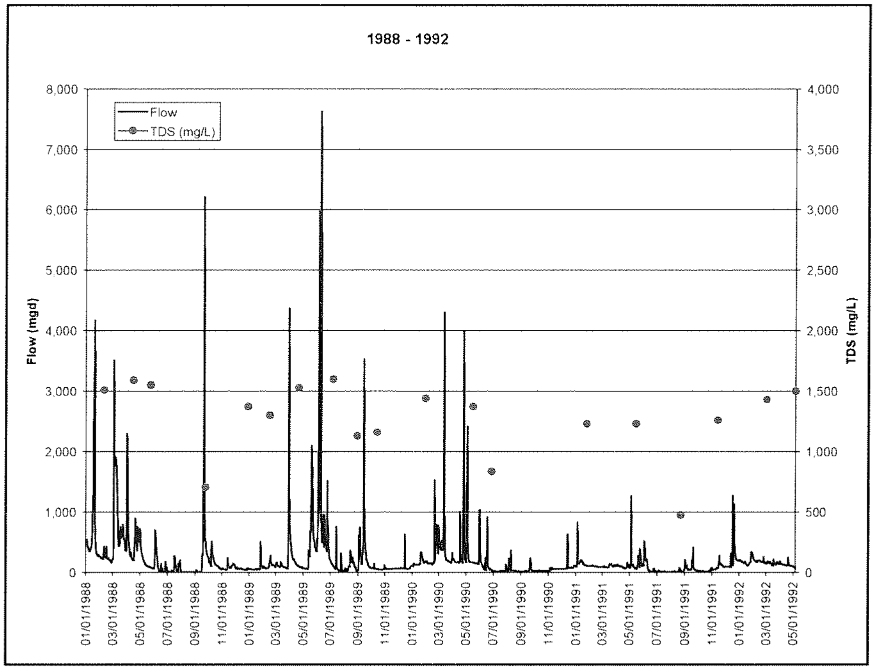


FIGURE 3-13
South Canadian River Raw Water Supply
Water Quality

TABLE 3-32
South Canadian River
Seasonal Water Quality

Parameter	October - February		March – June		July - September	
	Chloride	TDS	Chloride	TDS	Chloride	TDS
Number of Samples[a]	57	55	50	52	40	39
Maximum (mg/L)	440	1,750	490	1,810	380	1,660
Minimum (mg/L)	17	448	23	644	20	270
Average (mg/L)	236	1,285	284	1,326	97	905
95% Confidence (mg/L)	198 – 274	1,199 – 1,371	253 - 315	1,244 – 1,408	68 – 126	1,019 - 791

Note:
[a] Data adopted from USGS. Data represents water quality sampling from January 1979 through May 1992.

As previously mentioned, an alternative for mitigating the relatively high TDS levels in the South Canadian River raw water would be blending this water supply with raw water from Lake Thunderbird. Based on the TDS levels of the two raw-water sources, blended water TDS concentrations of 560 to 835 mg/L would be expected. Although this alternative increases the South Canadian River raw-water quality, it would significantly degrade the raw-water supply to the WTP. With blending, raw water TDS levels at the WTP would be increased by a factor of approximately 3.5.

The existing WTP does practice lime softening, which removes a portion of the dissolved solids. However, lime softening is a chemical precipitation process. Chemical use is dependent on raw-water quality. Lake Thunderbird and the South Canadian River are characteristically different water supplies. Although Lake Thunderbird water quality does vary, this water source provides Norman with a relatively consistent, good-quality raw water. On the other hand, raw water from the South Canadian is more variable and of lesser quality.

Consideration should also be given to the sensitivity of Lake Thunderbird and the South Canadian River. As compared to Lake Thunderbird, the South Canadian River watershed is more sensitive to potential microbial and/or chemical contamination due to municipal, agricultural, commercial, and industrial facility discharges and runoff. Such potential sources of contamination are more limited in the Lake Thunderbird watershed. As such, it is expected the South Canadian River would require a greater level of treatment (i.e., advanced oxidation, GAC, membranes, UV) to provide barriers against potential contamination. If the water sources were blended, the combination of sources would likely require such barriers as well.

Blending these water resources would require a terminal reservoir to allow proper mixing and stabilization, which would increase the required volume of raw-water storage. Additionally, the existing WTP would not only require additional capacity but also likely require treatment process upgrades to produce finished water of comparable quality to Lake Thunderbird finished water. Treatment process upgrades under this scenario would require capacity for Lake Thunderbird and South Canadian River raw water. If the two water resources were not blended, the existing WTP liquid-process train would not require process upgrades. A second treatment process train (or possibly WTP) with advanced unit processes could be dedicated to treating water supply from the South Canadian River. Thus, the required capacity for advanced treatment process unit(s) would be less. Therefore, for this water-supply plan, alternative development is based on parallel treatment, or non-blending, water storage options only.

Yield Basis. To fully realize an annual-average yield from the South Canadian River, raw water storage will be required for events when river flows can not support diversion. Daily flows from the 20-year historic record were used to ascertain storage requirements for the 50-mgd diversion practice discussed in the previous section. Table 3-33 briefly summarizes the four events that had the greatest number of consecutive days when the river flow could not support diverting a 5- to 50-mgd water supply and satisfy the diversion conditions discussed previously.

TABLE 3-33
South Canadian River - Low Flow Event Durations

Number of Consecutive Days	Occurrence Date
332	July 1980 – June 1981
164	July 1982 – December 1982
131	June 1994 – November 1994
126	June 1998 – October 1998

Minimum storage requirements were based on the volume required to satisfy a 10-mgd annual-average raw water supply during the greatest number of consecutive days (332 days) that river flows could not support diversion. Under this scenario, a minimum of 3.7-billion gallons (BG) of terminal storage would be required. Actual storage volume would be greater to provide an inactive pool for sedimentation and aesthetics, a freeboard for flood protection, and allocation for dikes and/or berms. In any event, comparing storage requirements to annual-average yield over these 20-year historic drought conditions, implementing such a storage reservoir seems excessive. The greatest number of consecutive low-flow days during 1980 and 1981 is over twice those that occurred from 1982 through 1999. Although this volume of storage would prove beneficial during such low-flow events, a significant volume would be relatively under utilized during the majority of the time.

A second alternative considers matching storage volume with diversion and yield over a year. For this scenario, storage requirements were based on the daily flows available for diversion during 1981, which correspond to the available annual-average yield of 10 mgd. Figure 3-14 illustrates the results from this scenario. As shown, the minimum required storage to satisfy an annual-average raw water supply of 10 mgd with diversion of up to 50 mgd from the South Canadian River is 1.9 BG.

A simulation was performed to route historical (1981 through 1999) daily-diversion flows available from the South Canadian River through a terminal storage volume of 1.9 BG with an assumed daily withdrawal rate of 10 mgd. Table 3-34 briefly summarizes this analysis.

With implementation of a minimum 1.9 BG of storage volume, water from storage would be available to satisfy raw water supply needs greater than 10 mgd during low-flow times of the year. A review of historic water production records from the WTP shows that production needs vary over a year to satisfy water consumption demands. Typically minimum water consumption demands occur during the winter months, while peak consumption occurs during the summer months.

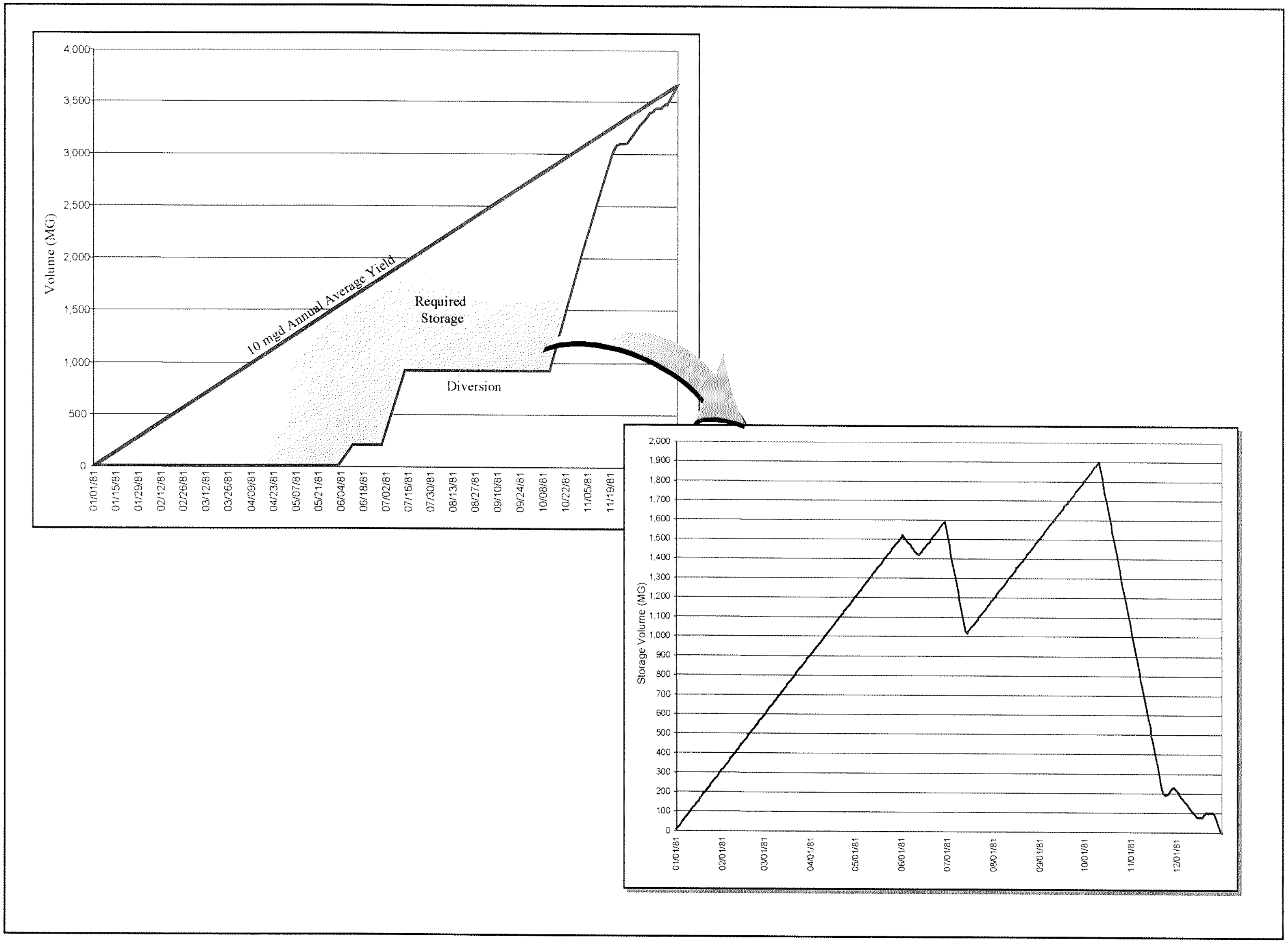


FIGURE 3-14
South Canadian River Raw Water Supply
Minimum Raw Water Storage Capacity Needs

TABLE 3-34
South Canadian River – Routing Simulation

Storage Utilized	Utilized Volume (MG)	Number of Events (years)
80 to 100%	1,520 to 1,900	3
60 to 80%	1,140 to 1,520	2
40 to 60%	760 to 1,140	1
20 to 40%	380 to 760	6
1 to 20%	19 to 380	6

Terminal storage for the potential South Canadian River raw water supply system could support varying production needs. Monthly-average production ratios adopted from the WTP were applied to the annual-average yield of 10 mgd from the South Canadian River reservoir. This resulted in monthly-average water production, or withdrawal from terminal storage, of 6.8 to 15 mgd. Annual-average supply remained at 10 mgd. Table 3-35 summarizes the monthly-average simulated withdrawals.

TABLE 3-35
South Canadian River Raw Water Supply
Monthly Average Peaking Supply Needs

Month	Annual Average Supply (mgd)	Monthly Average	
		Production Ratio	Supply Needs (mgd)
January	10	0.74	7.4
February	10	0.71	7.1
March	10	0.78	7.8
April	10	0.86	8.6
May	10	1.00	10
June	10	1.20	12
July	10	1.50	15
August	10	1.50	15
September	10	1.30	13
October	10	1.00	10
November	10	0.75	7.5
December	10	0.68	6.8
Annual Average	**10**	**1.00**	**10**

Note:
Monthly average ratios based on historic WTP operation records.

Monthly production needs were applied to the storage requirements while accounting for daily inflows or available diversion flows from the South Canadian River. Results from the analysis indicate that a minimum storage volume of 2.06 BG is required to meet monthly-average production needs of up to 15 mgd. Storage requirements under this scenario are approximately 8 percent greater than the minimum storage requirements for a daily withdrawal, or baseload production, of 10 mgd. Although a greater volume of storage is required, operating the reservoir as a peaking facility results in increased utilization of storage. Additionally, this scenario provides a greater water supply to augment other production facilities in meeting peak-consumption demands. Furthermore, implementation of this storage would accommodate treatment facility capacity greater than 15 mgd. Therefore, this treatment capacity could be utilized to a greater extent, if needed, during events when additional raw water from the South Canadian River is available. During such events, the annual-average yield from the South Canadian reservoir could effectively be greater than 10 mgd. Table 3-36 and Figure 3-15 depicts the 2.0 BG storage alternative simulation for the historical record.

TABLE 3-36
South Canadian River – 2.0 BG Storage Utilization

Storage Utilized	Utilized Volume (MG)	Number of Events (years)
80 to 100%	1,648 to 2,060	5
60 to 80%	1,236 to 1,648	1
40 to 60%	824 to 1,236	3
20 to 40%	412 to 824	3
1 to 20%	21 to 412	6

Implementing 2.0 BG of raw-water storage could provide Norman with an annual-average yield of 10 mgd under South Canadian River flow conditions observed for the historical record. Without storage, the South Canadian River could not reliably provide a 10 mgd annual-average yield over the historical record and would be limited during peak water consumption demands. Although, storage would be limited if South Canadian River flow conditions similar to those from 1980 through 1981 occurred again. Thus, developing a South Canadian River raw-water supply system with 2.0 BG of terminal storage should include a "redundant" water supply source. From the analysis, it is believed this redundant supply (i.e, Lake Thunderbird and GWA) would only need to balance the limited diversion and storage of raw water from the South Canadian River during extreme drought conditions.

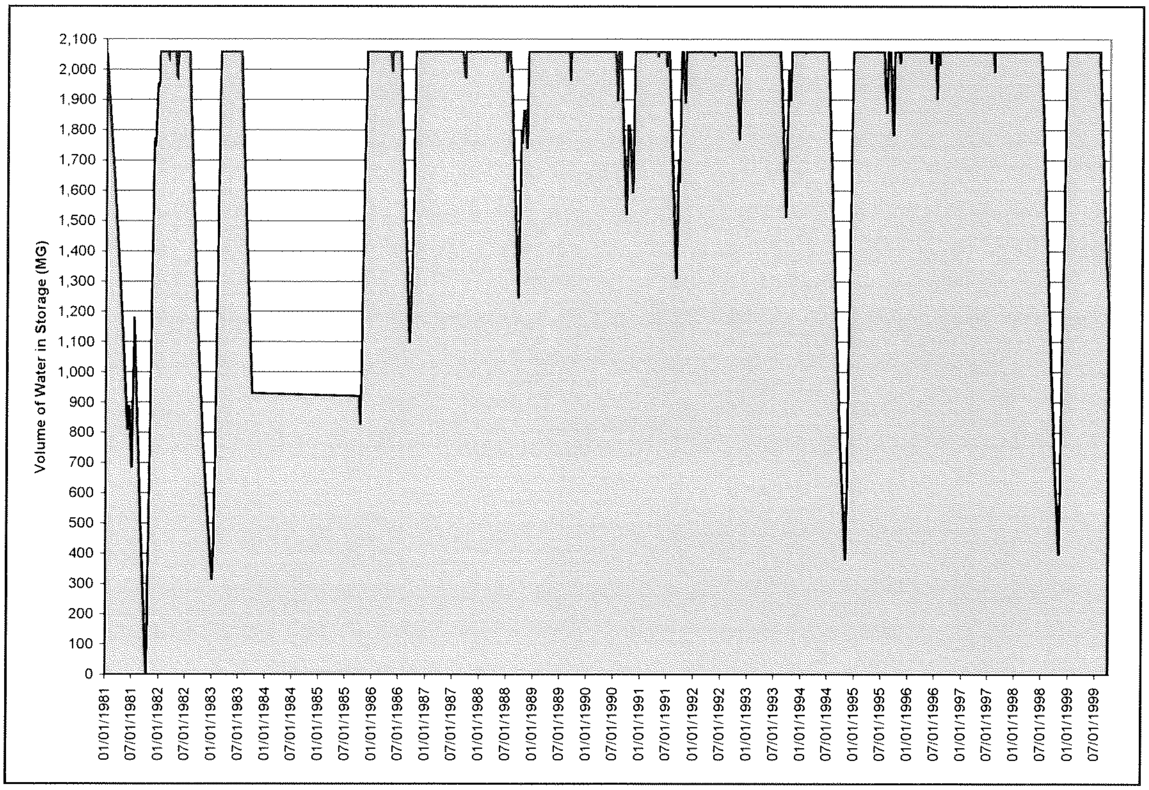


FIGURE 3-15
South Canadian Raw Water Supply – 2.0 BG Storage Utilization

Terminal Reservoir Options

With City staff input, two potential locations for the South Canadian raw water storage reservoir were identified for consideration under this plan.

West Side Storage. The first option considers development of the entire 2.0 BG storage volume in Northwest Norman in proximity to the South Canadian River. Although this option minimizes raw water conveyance infrastructure requirements, a new advanced Westside WTP would be required adjacent to the new reservoir. The area of consideration for this storage option includes two complete sections of land west of I-35, north of Franklin Road, and south of the City's corporate boundary. This area has little natural vertical relief. Thus, the reservoir would need to be constructed with berming of the land area. Also, the Canadian alluvial deposits occur in the western area. To prevent water loss from the reservoir to the subsurface alluvial, the reservoir must be located out of the river valley and over a confining layer of soil. Table 3-37 summarizes conceptual development of this South Canadian River reservoir option.

This option opens up possibilities for future reclamation opportunities with the effluent from the planned Northside WWTP. As identified in the ongoing *Norman Wastewater Master Plan*, the Northside WWTP discharge line to the South Canadian River could be readily tapped and routed to the Westside Terminal Reservoir for supplemental supply to the South Canadian River. Advanced water treatment technologies required for treatment of the South Canadian River raw water would be in place to accommodate processing of the reclaimed resource.

TABLE 3-37
South Canadian River Reservoir Option 1: Conceptual Development

Parameter	Quantity
Total Land	640 acres
Perimeter Buffer	20 ft
Berm Slope	2.5 : 1
Perimeter Buffer w/ Berm	120 ft
Nominal Water Surface Area	540 acres
Total Reservoir Volume (16 ft avg. depth)	8,400 ac-ft
Flood Control Pool (1.5 ft)	800 ac-ft
Sedimentation Pool (1 ft avg. depth)	500 ac-ft
Water Storage Volume (at 13.5 ft avg. Depth)	7,100 ac-ft

West and East Side Storage. The second option considered for locating South Canadian River storage includes splitting the required 2.0 BG volume between a West Side Reservoir and an East Side Reservoir. The advantage to this option is that all water treatment would be performed at the existing WTP site. Although raw water conveyance infrastructure would be more significant under this option, the reservoir could support one treatment location. A separate treatment train dedicated to the South Canadian River raw water supply could be implemented at the existing WTP site. The West Side Reservoir for this option would be essentially half that developed above. And, the East Side Reservoir would be developed as described in Section 3.3.3 for Lake Campbell. Table 3-38 summarizes conceptual development of this South Canadian River reservoir option.

As discussed previously, mixing of South Canadian River and Lake Thunderbird raw waters is not advised because it would require advanced water treatment technologies for the whole of the surface water supply. Unfortunately, the ability to obtain additional yield from Lake Thunderbird, as discussed in Section 3.3.3, would be lost with this option. On the positive side, this option would share the same reclamation potential as the first option, discussed above. The separate South Canadian River treatment train at the WTP would include advanced technologies to accommodate the reclamation source. Furthermore, this location is in proximity to the area for future development of the GWA wellfield. Thus, groundwater could be routed to the East Side Terminal Reservoir prior to treatment, if such treatment is required due to future wells with sensitivity for microbial or potentially other (such as arsenic) water quality issues.

TABLE 3-38
South Canadian River Reservoir Option 2: Conceptual Development

Parameter	Quantity
West Side Reservoir	
Anticipated Land Area	320 acres
Parameter Buffer	20 ft
Berm Slope	2.5 : 1
Parameter Buffer w/ Berm	120 ft
Nominal Water Surface Area	280 acres
Total Reservoir Volume (16 ft avg. depth)	4,400 ac-ft
Flood Control Pool (1.5 ft)	400 ac-ft
Sedimentation Pool (1 ft avg. depth)	280 ac-ft
Water Storage Volume (at 13.5 ft avg. depth)	3,720 ac-ft
East Side Reservoir	
Anticipated Land Area	200 acres
Natural Contour Boundary (elevation)	1,100 to 1,150 ft
Area Bound by natural 1,150 ft contour (existing)	160 acres
Total Storage	3,200 ac-ft
Average Depth	20 ft

As previously discussed, a raw water diversion infrastructure with 50-mgd capacity would be required to realize a 10-mgd annual-average yield from the South Canadian River. If the entire South Canadian River reservoir storage needs were constructed in eastern Norman, a 50-mgd raw water conveyance infrastructure would be required to route water supply from the South Canadian River, across the City, to the reservoir. Fortunately, this split storage scenario would allow the conveyance system capacity from the west reservoir to the east reservoir to be reduced. With implementation of two reservoirs, 50 mgd of raw water conveyance would be required from the South Canadian River to the West Side reservoir. This West Side reservoir would not only satisfy the majority of the raw water storage needs for flow variability in the South Canadian River (due to daily flow fluctuations and drought conditions), but would also serve to balance raw water supply needs for treatment in meeting water demands. Thus, raw water conveyance would be implemented to convey the annual-average yield (10 mgd) from the West Side Reservoir to the East Side Reservoir.

Advanced Treatment Requirements

Although water quality would remain characteristically poor with respect to TDS, especially during low flow, South Canadian River supply diversion to terminal storage would be maximized during high river flows when water quality is more acceptable. Advanced technologies, such as membranes and advanced oxidation processes, exist that provide treatment barriers to TDS and constituents associated with algae blooms or other water quality degradation. Membrane treatment processes are becoming more common for the treatment of public water supplies. This has improved process efficiency and hence cost effectiveness.

This considered, two treatment options were conceptually developed for the South Canadian River Alternative—a new Westside WTP and a separate process train at the existing WTP. As discussed, both options require water treatment processes advanced to those required for the treatment of surface water supply from Lake Thunderbird or Southeast Oklahoma. Figure 3-16 schematically summarizes the two South Canadian River options.

Option 1 realizes the economies to be saved through minimization of the raw water conveyance system, but would include implementation of a new Westside WTP adjacent to the terminal reservoir in Northwest Norman.

With Option 2, the existing WTP total production capacity would be expanded with an advanced treatment process train dedicated to the South Canadian River supply source only. The conventional (with lime softening) process treatment train would be maintained for processing supply from Lake Thunderbird only. Therefore, Option 2 could share common facilities with the existing WTP. For example, the existing treatment train (existing Norman WTP) and the new South Canadian River treatment train could share operations, maintenance, and chemical storage buildings, as well as common chemical-feed facilities (such as coagulant and disinfectant). However, existing facilities would require some degree of expansion to support the additional process train.

Another potential economy to be gained from Option 2 would be common disinfection facilities for water produced from the expanded Garber-Wellington Wellfield and the South Canadian River. As discussed in Section 3.3.2, planning for a disinfection facility for the expanded wellfield may be warranted because the wells are proposed in the unconfined portion of the aquifer. Because groundwater typically has low TOC concentration levels, the disinfection facility includes disinfection with free chlorine.

Similarly, South Canadian River supply treated through a new membrane process train will be stripped of all measurable TOC. Thus, the disinfection clearwells could be common for the South Canadian River process train and for the groundwater wells. Free chlorine was proposed to meet contact time because chlorine is a more powerful oxidant compared to chloramines, which are currently used at the existing WTP. Therefore, lower contact times are required when using chlorine in lieu of chloramines. This results in less clearwell or facility capacity requirements. Chloramines would continue to be utilized for distribution residual maintenance for all WTP finished water.

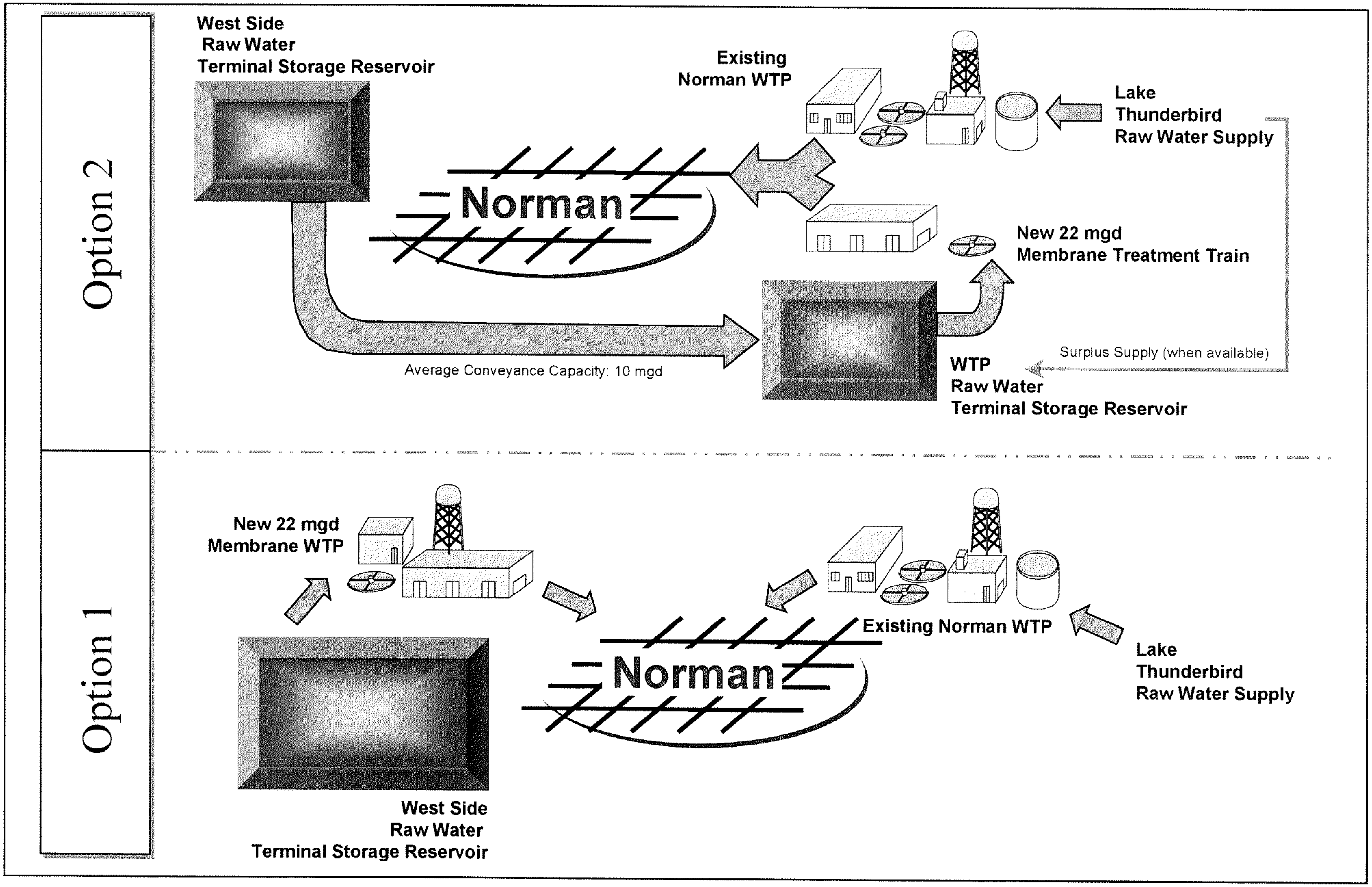


FIGURE 3-16
South Canadian River Water System
Options 1 & 2 Summary

Treatment scenarios for the South Canadian River consider implementation of membrane treatment technologies. As previously discussed, the South Canadian River has elevated TDS levels. Additionally, the water-supply source could be considered unprotected and sensitive to contamination due to the facility discharges into the river upstream of Norman. Membrane treatment technologies, such as nanofiltration (NF) or reverse osmosis (RO), provide a physical barrier for removing TDS, organic substances, and microbial contaminants. TDS removal of 60 percent to greater than 90 percent can be achieved with such treatment processes. Additionally, from 4- to 6-log removal of *Giardia, Cryptosporidium,* and viruses can be realized with these membrane technologies. Further, NF and RO treatment schemes remove organic contaminants such as pesticides and herbicides.

Additionally, less disinfectant doses are typically required due to the relatively high log removals of microbes. Thus, chlorine disinfection can typically be used with limited contact time to achieve disinfection requirements without forming unacceptable DBPs. All free chlorine will be converted to chloramines prior to distribution to be compatible with current residual maintenance practices and to prevent mixing dissimilar residuals out in the distribution system. As discussed in Section 2, greater control of microbes, disinfectants, and DBPs are required under recently finalized and anticipated SDWA regulations. In some cases, treatment levels increase depending on the raw-water source sensitivity classification.

For conceptual development, 22-mgd of treatment capacity for the South Canadian River has been assumed for development. Feed water recovery of 80 to 95 percent from membrane treatment plants can typically be expected. Considering 90 percent feed water recovery, a 22-mgd capacity plant would provide approximately 20 mgd of finished water supply to meet maximum-day demands. This results in a peak production factor (peak production divided by annual-average production) of 2, which is comparable to the existing Norman WTP operations.

Conceptual development of the process train includes pretreatment to remove TSS and conditioning to prevent membrane fouling, which is typical to extend membrane filter run times for membrane treatment plants treating surface waters. Pretreatment includes coagulation and sedimentation followed by micro-filtration (or screening). Following pretreatment, water would pass through membrane treatment units—NF or potentially low-pressure RO units. As previously discussed, primary disinfection practice includes contact with free chlorine in the clearwells. Free chlorine disinfectant residual is converted to chloramines following disinfection, but prior to distribution or blending with water from the existing WTP. Figure 3-17 presents the South Canadian River raw-water treatment scheme developed for this supply plan.

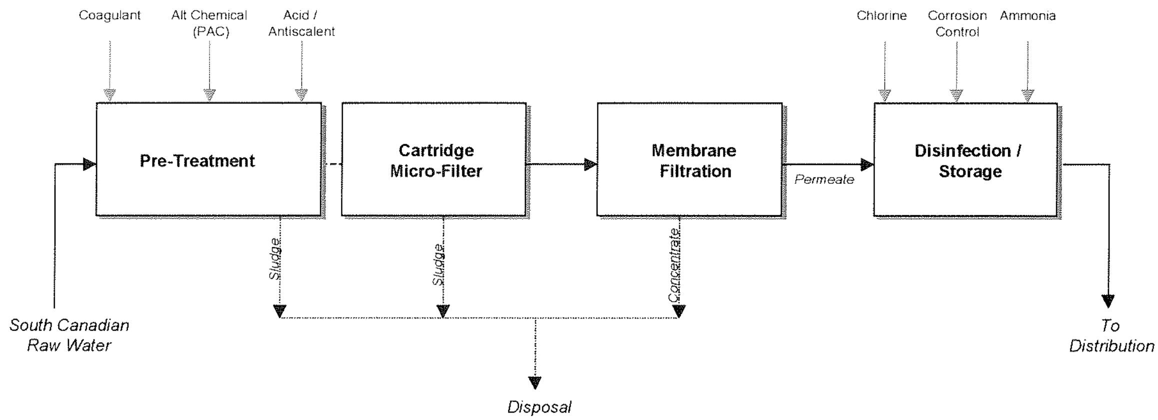


FIGURE 3-17
South Canadian Water System
Water Treatment Schematic

Recommendations

Two planning level options for implementing the South Canadian River as a water supply source have been developed for the 40-year planning horizon. These scenarios consider 10-mgd annual-average yield from the South Canadian River. Table 3-39 (next page) lists the proposed components for each option. In addition, the table provides estimates of capital cost opinions for each of the two options. Assumptions used to develop the cost estimates are provided in Appendix C. Additionally, comparative O&M cost estimates have been developed for each option and are presented in Table 3-40 on the following page.

For comparison, a monetary evaluation of the South Canadian River options was performed. This evaluation included a relative comparison of capital cost and annual O&M costs. Table 3-41 presents a summary of this monetary evaluation.

TABLE 3-41
South Canadian River Water System Monetary Evaluation

Option	Capital (x 1,000)	Annual O&M (x 1,000)
South Canadian River Water System Option 1	$76,990	$3,240
South Canadian River Water Supply Option 2	$87,150	$3,410

3.3.5 Oklahoma City Treated Water Purchase

Transmission Requirements

In 2000, the City of Norman completed construction of a 3-mile pipeline to facilitate the purchase of treated water from the City of Oklahoma City. The interconnection ties directly to the City's distribution system. It has been estimated that this new pipeline will provide transmission of up to 20 mgd. However, for the purposes of this plan, a more conservative

Table 3-39

Estimates of Capital Cost Opinions

South Canadian River: Option 1			South Canadian River: Option 2		
Item	**Cost (x 1,000)**	**Comment**	**Item**	**Cost (x 1,000)**	**Comment**
South Canadian River	$10,160	Water rights, intake structure, and pumping facility	South Canadian River	$10,160	Water rights, intake structure, and pumping facility
Raw Water Conveyance Piping	$3,780	50 mgd conveyance capacity	Raw Water Conveyance Piping: West Side Reservoir	$3,780	50 mgd conveyance capacity
West Side Reservoir	$20,570	Total storage of 8,400 acre-ft	West Side Reservoir	$10,760	Total storage of 4,400 acre-ft
South Canadian WTP	$42,480	Membrane WTP w/ 22 mgd treatment capacity	Raw Water Conveyance Piping: East Side (Campbell) Reservoir	$9,650	10 mgd conveyance capacity
			East Side (Campbell) Reservoir	$15,080	Total storage of 5,000 acre-ft
			Norman WTP: South Canadian Treatment Train	$37,720	Membrane treatment train w/ 22 mgd treatment capacity
Total Opinion of Cost	**$76,990**		**Total Opinion of Cost**	**$87,150**	

Table 3-40

Estimates of Annual O&M Cost Opinions

South Canadian River: Option 1			South Canadian River: Option 2		
Item	**Cost (x 1,000)**	**Comment**	**Item**	**Cost (x 1,000)**	**Comment**
Raw Water Conveyance Piping	$180	Annual average pumping of 36 mgd for 103 days per year and	Raw Water Conveyance Piping: West Side Reservoir	$180	Annual average pumping of 36 mgd for 103 days per year and
West Side Reservoir	$210	2% of estimated construction cost	West Side Reservoir	$110	2% of estimated construction cost
South Canadian WTP	$2,850	Annual average production of 10 mgd	Raw Water Conveyance Piping: East Side (Campbell) Reservoir	$270	Annual average pumping of 10 mgd for 365 days per year and
			East Side (Campbell) Reservoir	$150	2% of estimated construction cost
			Norman WTP: South Canadian Treatment Train	$2,700	Annual average production of 10 mgd
Total Opinion of Cost	**$3,240**		**Total Opinion of Cost**	**$3,410**	

estimate of 16 mgd was used, based on velocities, pipeline diameter, differential pressure, and operational experience. This considered, an additional pipeline would be required for transmission of water in excess of 16 mgd. Table 3-42 presents a summary of any necessary pipeline upgrades to support the plan alternatives, discussed in Section 3.4.

TABLE 3-42
OKC Transmission Pipeline Requirements

Plan	Required Pipeline Capacity (mgd)	Estimated Capacity of Current Pipeline (mgd)	Additional Required Capacity (mgd)
A	44.7	16	28.7
B	30.7	16	14.7
C	4.9	16	None
D	4.9	16	None
E	5.7	16	None
F	5.7	16	None

Notes:
Capacity based on maximum day demand.
Plans A through F are discussed in Section 3.4.

As shown in Table 3-42, additional transmission pipeline capacity would be required for Plan Alternatives A and B, relying on long-term treated water supply from OKC. Table 3-43 presents estimated transmission pipeline diameter and capital costs for each plan alternative. These estimated costs are used in the respective plan alternatives.

TABLE 3-43
Estimated Transmission Pipeline Expansion and Capital Cost

Plan	Estimated Pipeline Diameter [a] (in)	Estimated Capital Cost [b] (x $1,000)
A	32	2,028
B	21	1,331
C	None	None
D	None	None
E	None	None
F	None	None

Notes:
[a] Pipeline diameter based on 7 fps velocity, and 3 mile length.
[b] Potential right-of-way fees and easement costs are not included.

3.3.6 Oklahoma City Raw Water Purchase (SE Oklahoma)

OKC's Atoka pipeline, responsible for the conveyance of OKC raw water from Atoka and McGee Creek Reservoirs to Lake Stanley Draper, intersects the Hog Creek arm of Lake Thunderbird. With an agreement between the City of Norman and the City of OKC, raw water supply from the conveyance pipeline could be purchased and released into Lake Thunderbird and then transferred to a terminal reservoir before treatment. Expansion of the raw water conveyance system from Lake Thunderbird and expansion of the WTP would be required to realize this additional water supply.

Atoka Pipeline Metering/Outfall Station

Conveyance infrastructure required to facilitate the implementation of this alternative is negligible relative to the other new surface water resources considered. One of two approaches could be taken to secure a high-quality surface water supply from Atoka and McGee Creek Reservoirs in Southeast Oklahoma. As described above, OKC's Atoka Pipeline conveys raw water from the two Southeast Oklahoma reservoirs to Lake Stanley Draper, located north of Lake Thunderbird. Raw water could be released from Lake Draper to Lake Thunderbird via East Elm Creek or it could be diverted directly from the Atoka Pipeline into Lake Thunderbird via the Hog Creek arm.

Discussions with staff from the Cities of Norman and Oklahoma City indicate the Hog Creek diversion approach would be preferred. This approach would provide more control for measurement and reduce the potential for losses attributable to evaporation and infiltration. As such, it is assumed for this supply plan report that development of this alternative will include the Hog Creek diversion.

The 60-inch raw concrete cylinder pipe off the Macomb Pump Station, the last of six Oklahoma City Atoka pumping stations, would be tapped at the Hog Creek intersection with a 30-inch saddle tee to a combination metering and outfall structure. This station would include isolation valving and a flow meter/totalizer sized for 20 mgd. The conceptual cost opinion for the Atoka Pipeline outfall/metering station is valued at $250,000.

3.3.7 Hugo Reservoir (SE Oklahoma)

Conveyance Options

Raw water conveyed from Hugo Lake to the City of Norman presents more acceptable conveyance issues than the Kaimichi River and Sardis Reservoir alternatives, as withdrawal would not be restricted to certain times of the year. Although a longer pipeline would be required (130 miles), the capacity of the conveyance pipeline would be 30 mgd. As a result, three options are available for conveyance of 30 mgd, including the following.

- Lease capacity in the Atoka/McGee pipeline
- Buy capacity in the Atoka/McGee pipeline
- Construct a new conveyance pipeline

Option 1—Lease Capacity. As discussed previously, the Atoka/McGee pipeline is currently utilized by the OKC for conveying raw water from the Atoka and McGee Creek Reservoirs to Lake Stanley Draper. The McGee Creek pipeline, utilizing the McGee Creek Pump

Station, conveys water across 13 miles of 72-inch and 66-inch-diameter pipeline to the Atoka Reservoir. The Atoka pipeline, a 106-mile, 60-inch-diameter pipeline, uses six pump stations to route raw water from the Atoka Reservoir to Lake Stanley Draper.

The Atoka pipeline is rated at a capacity of 90 mgd, however, the pump stations are currently sized for 60 mgd. Data suggests that OKC conveys an average of approximately 50 to 55 mgd. Therefore, without an upgrade to the pump stations, an additional supply of only about 5 mgd could likely be pumped. However, with increased capacity at the pump stations, an additional 30 mgd could be conveyed in the Atoka pipeline. Understandably, the City of Norman would be interested as this matches the necessary water supply increase over the planning horizon.

The City could attempt to lease pipeline capacity for the 40-year project life from OKC, for a fee based on the number of gallons of water pumped. Pump upgrades should allow the pipeline to convey 90 mgd, which could route the water supply needed by the City over the planning horizon. However, this option does not give the City any control over conveyance issues because they do not own a portion of the pipeline. In addition, it assumes that conveyance of raw water by Oklahoma City will not increase over the planning horizon.

Based on information provided in the Water System Master Plan for the Oklahoma City Water Utilities Trust in 1990 and updating to Year 2000 dollars, it is estimated that lease charges would be on the order of $0.25 per thousand gallons pumped. This unit cost translates to an annual lease cost of approximately $2.75 million. In addition, annual increases are likely, raising the annual cost by about 3 percent per year. No additional annual O&M costs would be required here, as this cost is all-inclusive. The viability of this option is contingent on developing a mutually acceptable lease contract between the City and OKC. Preliminary discussions with representatives of OKC relative to this option were not favorable. However, continued dialogue is advised as opinions are subject to change as OKC prepares their justifications for intended use of waters of the Kiamichi Basin.

Option 2—Buy Capacity. Another option for conveyance of an additional 30 mgd to the City would involve a partnered effort with OKC to construct a new parallel pipeline. This effort would allow the City of Norman to achieve economies of scale, by dividing a portion of the project fixed costs among other partners. A very successful example for this approach is the COMCD partnership relative to Lake Thunderbird. As the long-term supply alternatives approach, it is likely that OKC will be interested in increasing their own water resource capacity. OKC has recently (February 2000) initiated a project to update their Water System Master Plan that will identify necessary infrastructure improvements. Development of this potential partnering option is dependant on future actions by OKC.

Although development of water resources from the Kiamichi River basin is uncertain, it is estimated that 80 to 140 mgd is available. Given the possibility of increased capacity in the existing Atoka/McGee pipeline (30 mgd), construction of another 90-mgd pipeline would give OKC the opportunity to purchase the remaining available water in the Kiamichi River basin. Therefore, this option will assume construction of a parallel 90-mgd pipeline to convey raw water from the Kiamichi River Basin to Central Oklahoma. This partnership would allow the City to finance only a portion of the new pipeline and respective pump stations proportional to their water purchase. However, given the fact that each partner will likely purchase water from different sources, raw water conveyance to the McGee Creek

Reservoir and parallel pipeline will not be a joint effort. Therefore, the City would be completely responsible for a 36-inch-diameter conveyance pipeline from Hugo Lake to the McGee Creek Reservoir, and would finance 33 percent of the cost of a common conveyance pipeline. These costs are reflected in Table 3-44, which summarizes the estimated conceptual capital costs to be incurred by the City for this conveyance pipeline.

TABLE 3-44
Preliminary Conveyance System Capital Cost Opinion
Partnered Conveyance from Hugo Lake

Component	Cost [a] (x $1,000)
Piping [b]	
Hugo Lake to McGee Creek Reservoir	$ 22,810
McGee Creek Reservoir to central Oklahoma (Common Pipeline)	48,718 [c]
Pump Stations	18,150 [c]
Total	$ 89,678

Notes:
[a] Costs for right-of-ways and easements not included.
[b] Assumes similar features as the existing Atoka/McGee pipeline (7 pump stations, 5 MG holding tank at each pump station, velocity of 7 fps, etc.)
[c] Cost illustrates 33 percent of total project cost

As shown, the estimated cost to the City would be nearly $90 million. This cost is considerably less than the cost for ownership of the entire pipeline, and would give the City some control due to ownership.

In addition to the estimated capital costs, annual O&M costs will factor largely into this option. Considerable O&M costs should be expected due to the size and length of the conveyance pipeline. Annual O&M costs for the new pipeline are expected to be similar to those of the Atoka/McGee pipeline, due to the similarities. Estimates for annual O&M on the Atoka/McGee pipeline, adjusted from 1992 dollars to 2000 dollars, are approximately $3.2 million, for conveyance of approximately 52 mgd. Adjusting these costs to reflect the maximum water pumped by the City (30 mgd), it is estimated that Norman's portion of the annual O&M cost for a new pipeline of similar capacity would not exceed $1.8 million. It should be noted that this estimated O&M cost reflects annual-average pumping of 30 mgd, which is projected in Year 2040. For the purposes of this evaluation, annual O&M costs for the conceptual pipeline was based on the projected pumpage gradient over the planning horizon.

Option 3—Construct New Pipeline. Construction of a new pipeline from Hugo Lake to the City of Norman would provide the City with the most control over their water resources. However, it would also be the most costly option. Using an annual-average flow of 30 mgd, a 36-inch diameter pipeline would be required. The associated costs are summarized in Table 3-45.

TABLE 3-45
Preliminary Conveyance System Capital Cost Opinion
Conveyance from Hugo Lake

Component	Cost [a] (x $1,000)
Piping [b] – 36 inch diameter, 130 miles	$ 164,736
Pump Stations	55,000
Total	$ 219,736

Notes:
[a] Costs for right-of-ways and easements not included.
[b] Assumes similar features as the existing Atoka/McGee pipeline (7 pump stations, 5 MG holding tank at each pump station, velocity of 5 fps, etc.)

This cost is considerably less than that for the required 90-mgd pipeline to develop the Kiamichi River alternative. In addition, Hugo Lake provides natural storage, alleviating the necessity for incremental volume of a new terminal reservoir. Although this option is more costly than a partnership with the OKC on a larger pipeline, it does give all control to the City of Norman.

In addition, the City would be responsible for all annual O&M costs. Given the similarity to the Atoka/McGee pipeline, it is estimated that annual O&M costs would be approximately $2.0 million at Year 2040 design conditions. Again, actual O&M costs for the purposes of this study were based on the projected pumpage gradient for the planning horizon.

Recommendation

As previously discussed, there has been keen interest, of late, in developing water supply from the Kiamichi River Basin by Central Oklahoma communities. In addition to Norman and Oklahoma City, Edmond, Moore, Yukon, Piedmont, Purcell, and ACOG, other Central Oklahoma municipalities have been active in discussing the potential to develop water resources in Southeast Oklahoma. Development of conveyance infrastructure will be a major factor for transferring water supply from the Kiamichi River Basin to Central Oklahoma. Considering the capital investment and annual O&M costs for such infrastructure, it is reasonable to assume that Oklahoma City or other Central Oklahoma communities would be interested in developing a partnership for implementation of water supply from the Kiamichi River Basin. With these potential possibilities in mind, a partnership scenario for development of conveyance infrastructure (Option 2) to transfer water from Hugo Reservoir to Norman is assumed for this alternative.

3.3.8 Finished Water Production Facilities

WTP Facilities

Assuming adequate in-system distribution storage, maximum-daily demands represent the quantity of water that must be produced by a water system. The City's existing water production facilities include the Norman WTP and the City's wellfield, comprised of 31 wells. The Norman WTP produces water from Lake Thunderbird. The City's wellfield produces water from the Garber-Wellington Aquifer. Assessment of each water supply source and associated production facilities was presented in Section 2.

The existing Norman WTP has a rated capacity of 14 mgd, although existing facilities at the WTP could likely support a firm production capacity of 17 mgd. Water produced from the City's wells augment WTP production in meeting maximum-day demands. The City's wells are operated as peaking facilities, producing up to 8.1 mgd over a short duration to meet maximum-day demands.

Based on projected water demands for the 40-year planning horizon, the Year 2040 maximum-day demand target is 65.7 mgd. Considering the existing production capacity of 25.1 mgd (17 mgd from the WTP and 8.1 mgd from wells), water production capacity must be increased by 41 mgd. WTP expansion is only required for plan alternatives using new raw water supply sources. This considered, incremental WTP expansion capacity can be discounted for all planned additional groundwater production. This includes development of a new wellfield with an additional 10-mgd annual-average groundwater supply that could provide a peaking capacity of 14 mgd. With this additional 14-mgd groundwater peaking supply, an incremental WTP expansion capacity of 27 mgd would be required to process additional raw surface water to meet the projected 2040 production target of 65.7 mgd.

Provided herein is a cost opinion generated for the Norman WTP planning horizon build-out alternative of 44 mgd (17 mgd existing and 27 mgd expansion). This build-out scenario corresponds to the incremental 27-mgd expansion component to the existing WTP noted previously. For this level of analysis, WTP expansion components and cost opinions assume the WTP build-out scenario will consist of process trains in operation parallel to the existing WTP process train. Additionally, conceptual costs have been developed for a new sludge process train for this build-out scenario, based on full WTP capacity. For Year 2040 WTP build-out capacity of 44 mgd with similar treatment process trains, Table 3-46 lists the proposed number of process units and planning criteria for each parallel WTP expansion component. In addition, Table 3-46 provides the cost opinions for each expansion component.

If expansion of the Norman WTP is required under the water supply plan selected by the City, a phased implementation is fully anticipated to realize the Year 2040 build-out treatment capacity. However, costs provided herein are for Year 2040 build-out capacity of the WTP expansion. At this stage of the planning process, it is not necessary to consider project phasing implications. A phasing plan and corresponding capital outlay throughout the 40-year planning horizon is discussed for the selected Water Supply Plan scenario in Section 4.

In addition to capital costs for the WTP expansion, a conceptual O&M cost opinion was generated for the WTP expansion scenario. Annual O&M costs are based on City-provided monthly accounting of O&M costs for the existing WTP during 1998 (at a WTP annual-average production rate of 8.7 mgd). These costs for ongoing WTP O&M include such factors as chemicals, contracts, supplies, repairs, power, and labor. These costs were adjusted to reflect increased production capacity associated with a Year 2040 build-out WTP

Table 3-46
Proposed Year 2040 WTP Expansion Components

Capacity Component	WTP Capacity	Conceptual Expansion Criteria
Existing WTP	17 mgd	Contigent on raw water conveyance capacity
Incremental WTP Expansion	27 mgd	Required additional production capacity
Total	**44 mgd**	Proposed 2040 build out capacity

Process Component	Additional Number of Units	Estimated Capital Cost (x $1,000)	Conceptual Expansion Criteria
Upflow Clarifiers	7	4,875	1.0 gpm/ft^2 uplflow rate (<1.75 gpm/ft^2)
Recarbonation Basin	4	3,000	20 minute detention time
Conventional Filters	10	11,720	4 gpm/ft^2 filtration rate
Elevated Filter Backwash Tank	1	720	15 min. backwash at a rate of 20 gpm/ft^2
Above Ground Clearwell	2	3,325	2 hour minimum detention time
High Service Pump Station	1	918	WTP capacity
Chemical Building and Facilities	1	2,835	WTP capacity
Administration/O&M Building Improvements	1	1,080	N/A
Sludge (Mechanical) Process Train [a]	1	7,641	WTP capacity
Subtotal 1		**36,114**	
Contigencies (20%)		7,223	
Total		**43,337**	

Notes:
[a] Cost allowances include two new semi-batch process trains consisting of gravity thickeners/blend units, belt filter press or centrifuge mechanical dewatering units, polymer feed systems, dry cake conveyance system, filtrate return system, terminal storage and load out, and dewatering building.
[b] No additional land area is assumed.

capacity of 44 mgd. Table 3-47 presents the conceptual annual O&M cost opinions for the incremental WTP expansion component.

TABLE 3-47
Estimated WTP
Annual O&M Cost Opinion at Design Condition

Component	WTP Capacity
Existing WTP	17 mgd
Incremental Expansion Capacity	27 mgd
Total	**44 mgd**
Cost Component	**Annual O&M Cost (x 1,000)**
Existing WTP	$ 1,604
Incremental Expansion Capacity	3,690
Total	**$ 5,294**

Note:
Cost opinion based on annual average production rate.

Groundwater Treatment Facilities

As previously discussed one water supply alternative for the planning horizon is expansion of the City's wellfield. A total of 30 new wells are proposed for the planning horizon. The area most likely for locating new wells is in the unconfined recharge zone of the Garber-Wellington Aquifer. Under the anticipated GR (discussed in Section 2), groundwater produced from the unconfined portion of the aquifer would be susceptible to a "sensitive" classification. If this is the case and a water quality deficiency is found through sanitary surveys, hydrogeologic sensitivity assessment, and/or monthly source water monitoring, the City would be required to provide disinfection based on 4-log inactivation/removal of viruses. With this in mind, disinfection facilities are developed for groundwater supply produced from the proposed wells.

As discussed in Section 2, disinfection is based on meeting disinfection contact times (CT), which depends on the disinfection practice, targeted microbial contaminant, and water properties. Disinfection at each wellhead has limited potential when considering the number of chemical feed points and required CT for 4-log inactivation of viruses. Therefore, a common clearwell facility is proposed to collect and retain the well water to ensure that proper CTs are achieved prior to distribution. To minimize tank volume, the proposed primary (microbial inactivation) disinfection practice is free chlorine for the groundwater supply, as required CTs for virus inactivation are less for free chlorine than for chloramines (free chlorine is a more powerful oxidant). However, the City's current disinfection practice at the WTP utilizes chloramines for both primary and secondary (residual maintenance) disinfection. Mixing of dissimilar disinfectant residuals in the distribution system is not recommended due to the difficulty in maintaining minimum required disinfection residuals and consequential taste and odor problems. Chloramine disinfection practice at the WTP was initiated to control the formation of disinfection byproducts, which are currently regulated under the SDWA. Groundwater produced from the GWA is expected to have low TOC, a precursor to DBP. As such, it is likely that chlorine disinfection would not result in elevated DBP formation. For secondary disinfection purposes, the proposed groundwater disinfection facility includes chemical (ammonia) feed facilities to convert free chlorine to chloramine residual following primary disinfection.

As the proposed wells are in northern Norman in relatively close proximity to the WTP, the proposed site location for the groundwater disinfection facility is at the WTP, thereby providing common treatment facilities and chemical storage location. Table 3-48 summarizes the proposed groundwater disinfection facility. The table also provides conceptual cost opinions for the disinfection facility.

TABLE 3-48
Proposed New Wellfield Piping and Groundwater Disinfection Facility
Preliminary Opinions of Cost

Component	Number of Units	Planning Criteria	Estimated Capital Cost (x $1,000)
Transmission Piping	See note [a]	7 ft/s flow velocity	$ 6,125 [b]
Disinfection Clearwell (common wall)	2	45 minute minimum detention time [c]	570
Chemical Building and Facilities	1	Treatment Process	550
High Service Pump Station	1	Production Capacity	612
Subtotal 1			**$ 7,857**
Contingencies (20%)			1,571
Total			**$ 9,428**

Notes:

[a] Transmission piping based on proposed well alignment. Piping cost include:
- 47,520 ft of 8-inch diameter pipe
- 26,400 ft of 10-inch diameter pipe
- 6,400 ft of 12-inch diameter pipe
- 0,560 ft of 18-inch diameter pipe
- 5,840 ft of 24-inch diameter pipe

[b] Potential right-of-way, easement, and land acquisition costs are not included.

[c] Assumes free chlorine disinfection with chloramine conversion.

Similar to the WTP alternatives, conceptual O&M cost opinions were generated for GWA groundwater supply production associated with the existing wellfield and proposed expansion wells. Annual O&M costs are based on City-provided monthly accounting of O&M costs for the existing wellfield during the last complete year of data (1998 at a wellfield annual-average production rate of 3.5 mgd). The costs for ongoing wellfield O&M include such factors as contracts, supplies, repairs, power, and labor. Costs were adjusted to reflect increased production capacity associated with the proposed 30 new wells at an estimated annual-average and peak-production capacity of 10 mgd and 14 mgd, respectively. In addition, annual O&M cost opinions were generated for the proposed disinfection system for the new wells. Table 3-49 presents the conceptual annual O&M cost opinions for existing and proposed groundwater wells.

TABLE 3-49
Estimated Wellfield
Annual O&M Cost Opinions

Component	Annual-Average Capacity
Existing Wellfield (28 wells + 3 new wells)	4.2 mgd
Incremental Wellfield Expansion (30 wells)	10 mgd
Total	**14.2 mgd**
Cost Component	**Annual O&M Cost (x 1,000)**
Existing Wellfield (28 wells + 3 new wells)	$ 307
New Wellfield (30 new wells)	877
New Wellfield Disinfection System	45
Total	**$1,229**

3.3.9 Short List Summary

As illustrated on Figure 3-18, three of the six alternatives can satisfy the long-term incremental resource capacity need of 30 mgd (or 41.9 less 12.6 mgd). However, only OKC treated water alternative meets all capacity needs for the entire planning horizon. As developed herein, the South Canadian River and Expanded GWA alternatives both have a maximum-yield potential of 10 mgd. As such, these two alternatives must be considered as supplemental to one or more other alternatives in meeting the planning horizon needs. The Lake Thunderbird Additional Yield alternative is not illustrated as a quantified option on Figure 3-18 due to the unreliable nature of available flood pool and unused Midwest City and Del City allocations. Nevertheless, economics dictate it as a viable option when available.

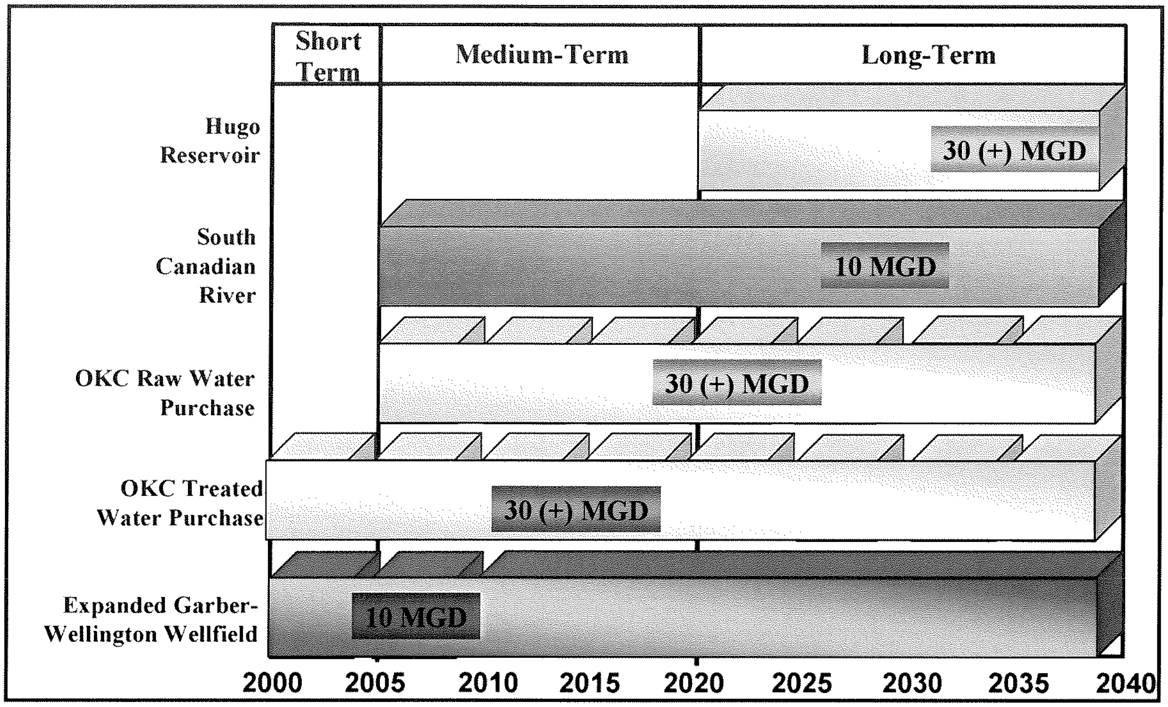


FIGURE 3-18
Short-Listed Water Resources Alternatives

3.4 Plan Alternatives Analysis

3.4.1 General

With identification and characterization of the six most viable water resource alternatives available to the City of Norman for satisfying the 40-year planning horizon, the task at hand is to identify which combination of water resources formulates the best Strategic Water Supply Plan. Since no single water resource alternative can satisfy short-, medium-, and long-term needs without infrastructure improvements, several Plan Alternatives have been assembled for analysis.

To cost effectively and reliably meet the projected planning curves developed in Section 1, Baseline Development, six Plan Alternatives were developed by combining differing water resource capacities. To this end, primary consideration was given to maintaining as well as expanding the City's existing water supply sources and to best position the City to capitalize on potential new emerging water resources, when needed, over the planning horizon. Historically, the City of Norman has benefited from the operational flexibility of two resources (Lake Thunderbird and the GWA). Therefore, this multiple supply resource base was desired to prevent reliance on a single source of supply. Furthermore, respective implementation windows of each water resource was a strong determining factor when assembling each Plan Alternative to satisfy not only the Year 2040 needs, but also the short- to mid-term needs.

3.4.2 Plan Alternatives Assembly

The foundation for assembling Plan Alternatives was full utilization of the City's existing water resources. Following existing resources, expansion of the City's groundwater resource was emphasized. Then, new water resources were added, as needed, to make up the deficit between the assembled capacity and the projected annual-average demands over the planning horizon. The contributions by respective water resources to each Plan Alternative are presented in Table 3-50. Major components are identified for each of the six Plan Alternatives in the following summary, Table 3-51, and illustrated on Figures 3-19 through 3-24.

- **Plan A** - "Do-Nothing Alternative" - sources of supply include the existing wellfield, Lake Thunderbird, and OKC-treated. Existing resources are maintained at current capacity. Purchase of treated water from OKC is required to satisfy the majority portion of the 2040 demand.
- **Plan B** - "Garber-Wellington Aquifer Alternative" - sources of supply include the existing wellfield, Lake Thunderbird, a 30-wellhead expanded wellfield, and OKC treated. With yield from the expanded wellfield, this alternative offers reduced reliance on treated water from Oklahoma City.
- **Plan C** - "Southeast Oklahoma Alternative" - supply sources are same as for Plan B, however, the City would transition to raw water purchase from OKC in the mid-term. This alternative would maintain the City's position as a partner for future use of a high-quality supply from sources in Southeast Oklahoma.
- **Plan D** - "Hugo Reservoir Alternative" - sources of supply are similar to Plan C, differing in the transition to the Hugo Reservoir for long-term raw water supply and with no reliance on purchased water from OKC.
- **Plan E** - "South Canadian Two Reservoirs Alternative" - sources of supply include the existing wellfield, Lake Thunderbird, expanded wellfield, and South Canadian River. Supply from the South Canadian would be utilized to support two storage reservoirs, and hence, one WTP facility for the Lake Thunderbird and South Canadian River water supplies. Purchase of OKC treated water is needed in the long term.
- **Plan F** - "South Canadian One Reservoir Alternative" - sources of supply are similar to Plan E, differing with respect to implementation of one South Canadian Reservoir and a new Westside WTP dedicated to the raw water supply from the river.

3.4.3 Matrix Analysis

Following assembly of the six Plan Alternatives, conceptual cost information was developed and compiled to define the cost effectiveness for each alternative relative to the others. Following this, the Plan Alternatives were evaluated for their ability to satisfy a list of non-monetary criteria. The results of both the monetary and non-monetary evaluations were compiled and utilized in a matrix analysis to select the recommended 2040 Strategic Water Supply Plan for the City of Norman.

Table 3-50
Norman Strategic Water Supply Plan
Water Supply Plan Alternatives

Plan	Range / Year / Targeted Demand	Short 2000-2005 22.0 mgd	Medium 2005-2020 30.0 mgd	Long 2020-2040 41.9 mgd
Plan	**Resources**	**(mgd)**	**(mgd)**	**(mgd)**
A	Lake Thunderbird Existing Supply	8.4	8.4	8.4
	Existing Wellfield (including 3 new wells)	4.2	4.2	4.2
	OKC Treated Water Purchase	9.4	17.4	29.3
	Plan A Total	**22.0**	**30.0**	**41.9**
B	Lake Thunderbird Existing Supply	8.4	8.4	8.4
	Existing Wellfield (including 3 new wells)	4.2	4.2	4.2
	New Wellfield (30 wells)	4.4	10.0	10.0
	OKC Treated Water Purchase	5.0	7.4	19.3
	Plan B Total	**22.0**	**30.0**	**41.9**
C	Lake Thunderbird Existing Supply	8.4	8.4	8.4
	Existing Wellfield (including 3 new wells)	4.2	4.2	4.2
	New Wellfield (30 wells)	4.4	10.0	10.0
	OKC Treated Water Purchase	5.0	-	-
	OKC Raw Water Purchase	-	7.4	19.3
	Plan C Total	**22.0**	**30.0**	**41.9**
D	Lake Thunderbird Existing Supply	8.4	8.4	8.4
	Existing Wellfield (including 3 new wells)	4.2	4.2	4.2
	New Wellfield (30 wells)	4.4	10.0	10.0
	OKC Treated Water Purchase	5.0	-	-
	OKC Raw Water Purchase	-	7.4	-
	Hugo Reservoir	-	-	19.3
	Plan D Total	**22.0**	**30.0**	**41.9**
E	Lake Thunderbird Existing Supply	8.4	8.4	8.4
	Existing Wellfield (including 3 new wells)	4.2	4.2	4.2
	New Wellfield (30 wells)	4.4	10.0	10.0
	South Canadian River	-	7.4	10.0
	OKC Treated Water	5.0	-	9.3
	Plan E Total	**22.0**	**30.0**	**41.9**
F	Lake Thunderbird Existing Supply	8.4	8.4	8.4
	Existing Wellfield (including 3 new wells)	4.2	4.2	4.2
	New Wellfield (30 wells)	4.4	10.0	10.0
	South Canadian River	-	7.4	10.0
	OKC Treated Water	5.0	-	9.3
	Plan F Total	**22.0**	**30.0**	**41.9**

Notes:

Plans A, B, C, and D include an East Side Terminal Reservoir.

Plan E includes development of South Canadian River with West and East Side Terminal Reservoirs and new treatment train at the existing WTP site location

Plan F includes development of S.C. River with a West Side Terminal Reservoir and a new WTP.

Table 3-51
Strategic Water Supply Infrastructure Capital Components

Plan	Resources	Source of Supply	Conveyance/Transmission	Treatment/Production
A	Lake Thunderbird Existing Supply Existing Wellfield OKC Treated Water Purchase	None	None Expanded transmission from OKC	None
B	Lake Thunderbird Existing Supply Existing Wellfield	None	None	None
	New Wellfield (30 wells)	Development of 30 new wells. Wellhead Land puchase (30 acres)	New wellfied transmission system	Disinfection clearwells and HSPS
	OKC Treated Water Purchase	None	Expanded transmission from OKC	None
C	Lake Thunderbird Existing Supply Existing Wellfield	None	None	None
	New Wellfield (30 wells)	Development of 30 new wells. Wellhead Land puchase (30 acres)	New wellfied transmission system	Disinfection clearwells and HSPS
	OKC Treated Water Purchase	None	None	None
	OKC Raw Water Purchase	Atoka pipline release to Thunderbird	Expanded pumping and transmission to WTP.	Expanded WTP
D	Lake Thunderbird Existing Supply Existing Wellfield	None	None	None
	New Wellfield (30 wells)	Development of 30 new wells. Wellhead Land puchase (30 acres)	New wellfied transmission system	Disinfection clearwells and HSPS
	OKC Treated Water Purchase	None	None	None
	OKC Raw Water Purchase	Atoka pipline release to Thunderbird	Expanded pumping and transmission to WTP.	Expanded WTP
	Hugo Reservoir	Water rights/storage aquisition	Hugo conveyance system	
E	Lake Thunderbird Existing Supply Existing Wellfield	None	None	None
	New Wellfield (30 wells)	Development of 30 new wells. Wellhead Land puchase (30 acres)	New wellfied transmission system	Disinfection clearwells and HSPS
	South Canadian River	Water rights/storage aquisition	South Canadian River conveyance system with two storage reservoirs	Expanded WTP
	OKC Treated Water	None	None	None
F	Lake Thunderbird Existing Supply Existing Wellfield	None	None	None
	New Wellfield (30 wells)	Development of 30 new wells. Wellhead Land puchase (30 acres)	New wellfied transmission system	Disinfection clearwells and HSPS
	South Canadian River	Water rights/storage aquisition	South Canadian River conveyance system with one storage reservoir	New WTP
	OKC Treated Water	None	None	None

Note:
Plans A, B, C, D and F include new terminal reservoir (Lake Campbell) to support the LakeThunderbird additional yield conditional alternative.

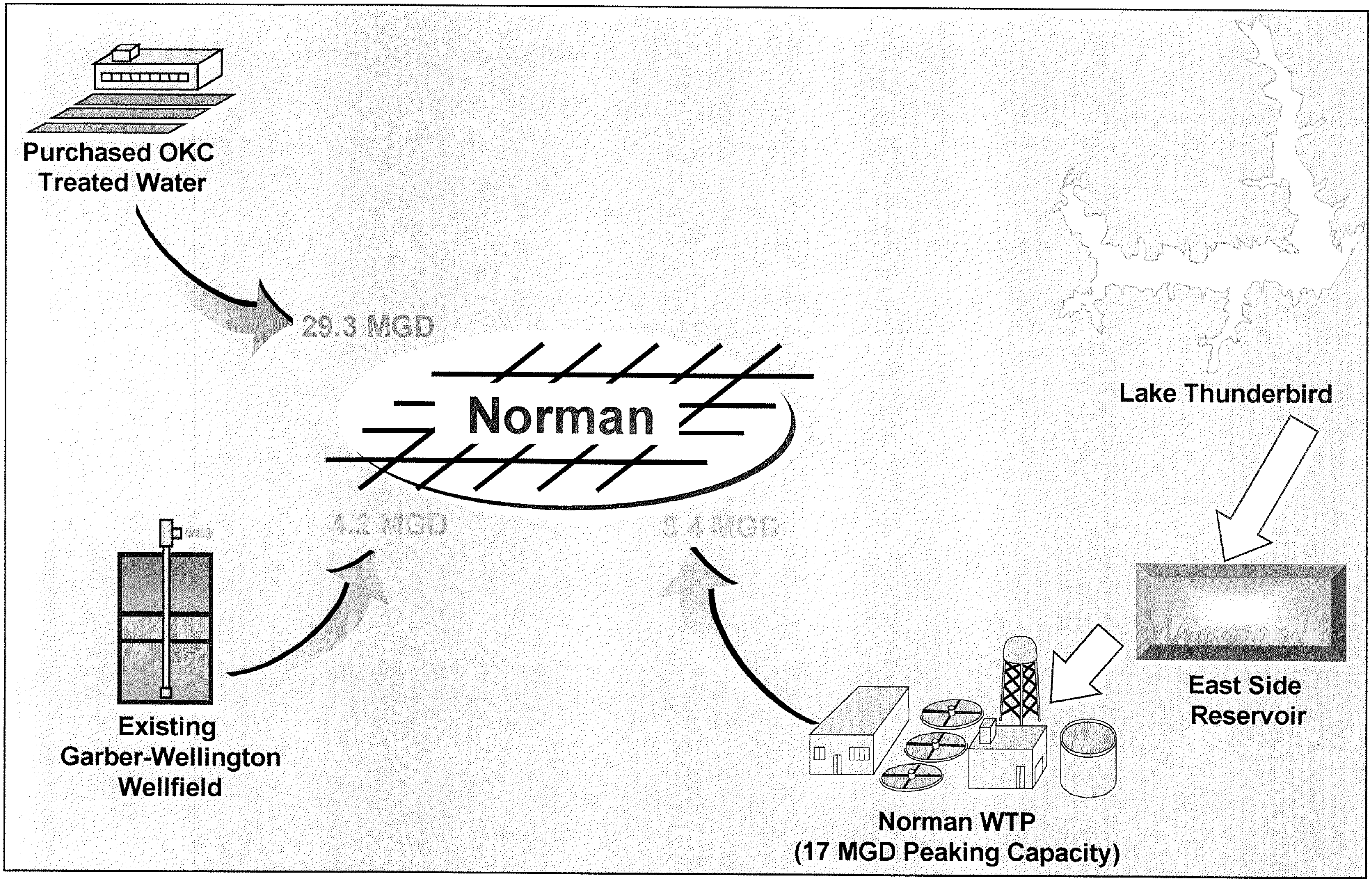


FIGURE 3-19
Norman Strategic Water Supply Plan
Plan Alternative A

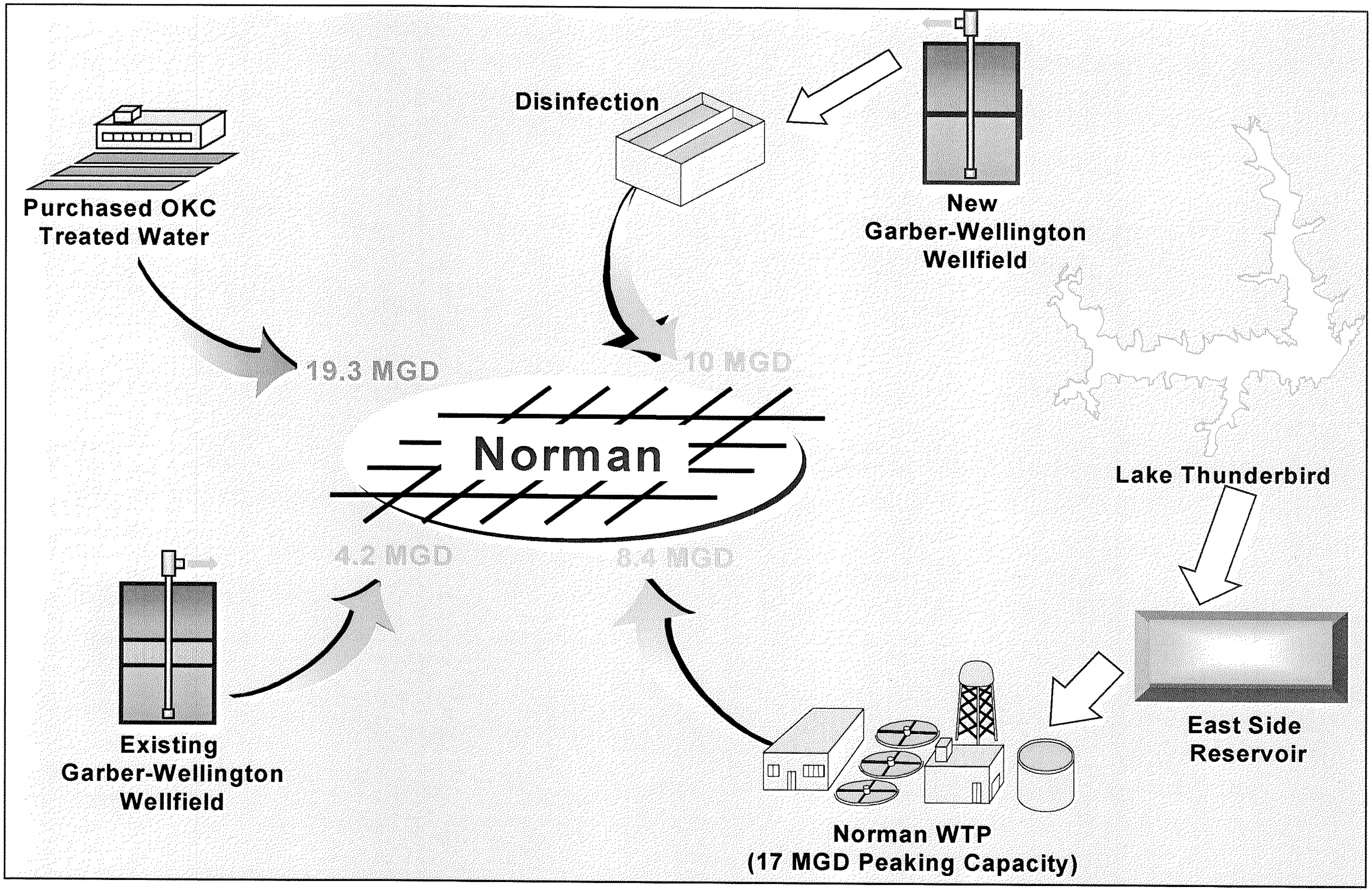


FIGURE 3-20
Norman Strategic Water Supply Plan
Plan Alternative B

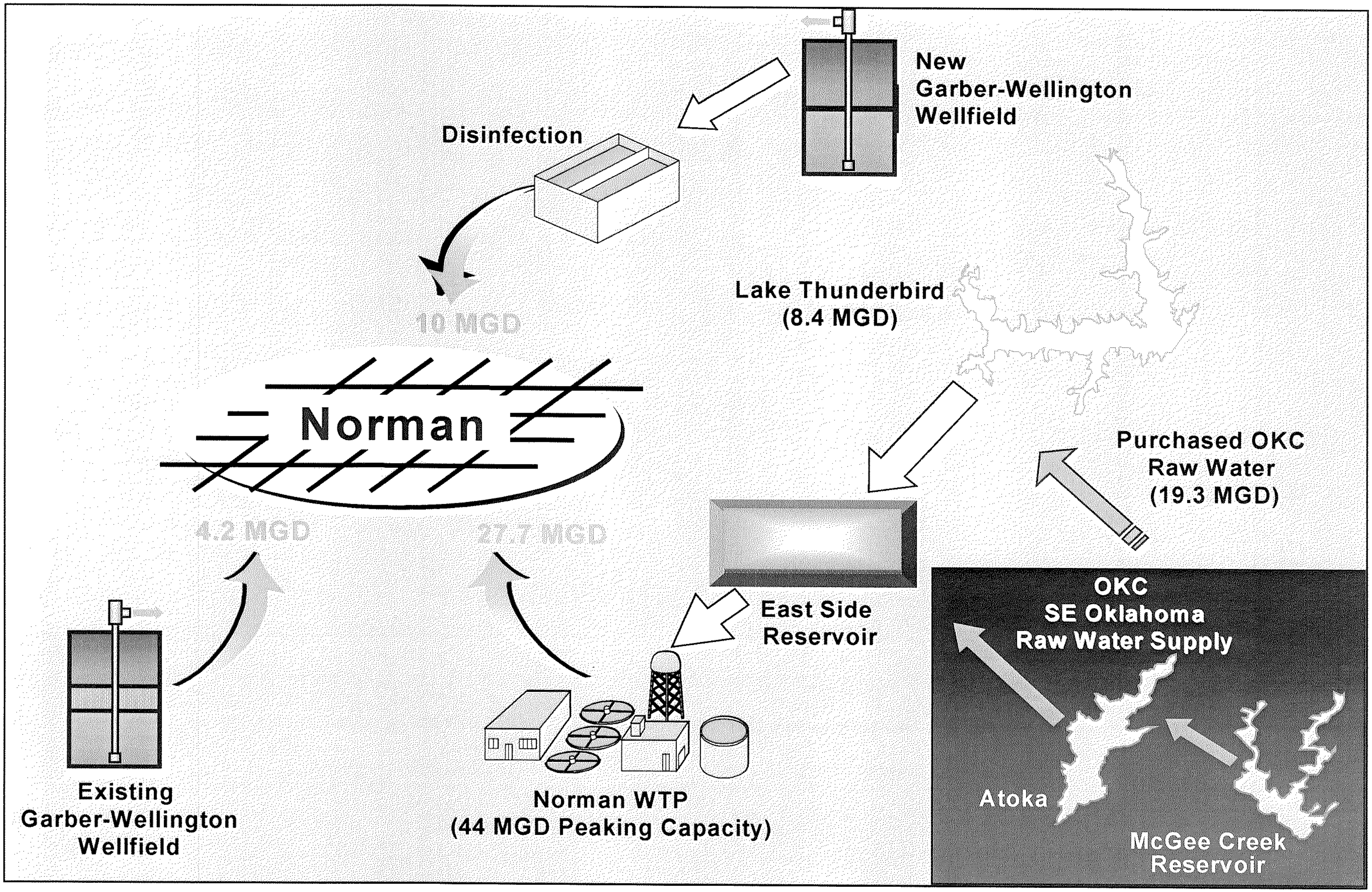


FIGURE 3-21
Norman Strategic Water Supply Plan
Plan Alternative C

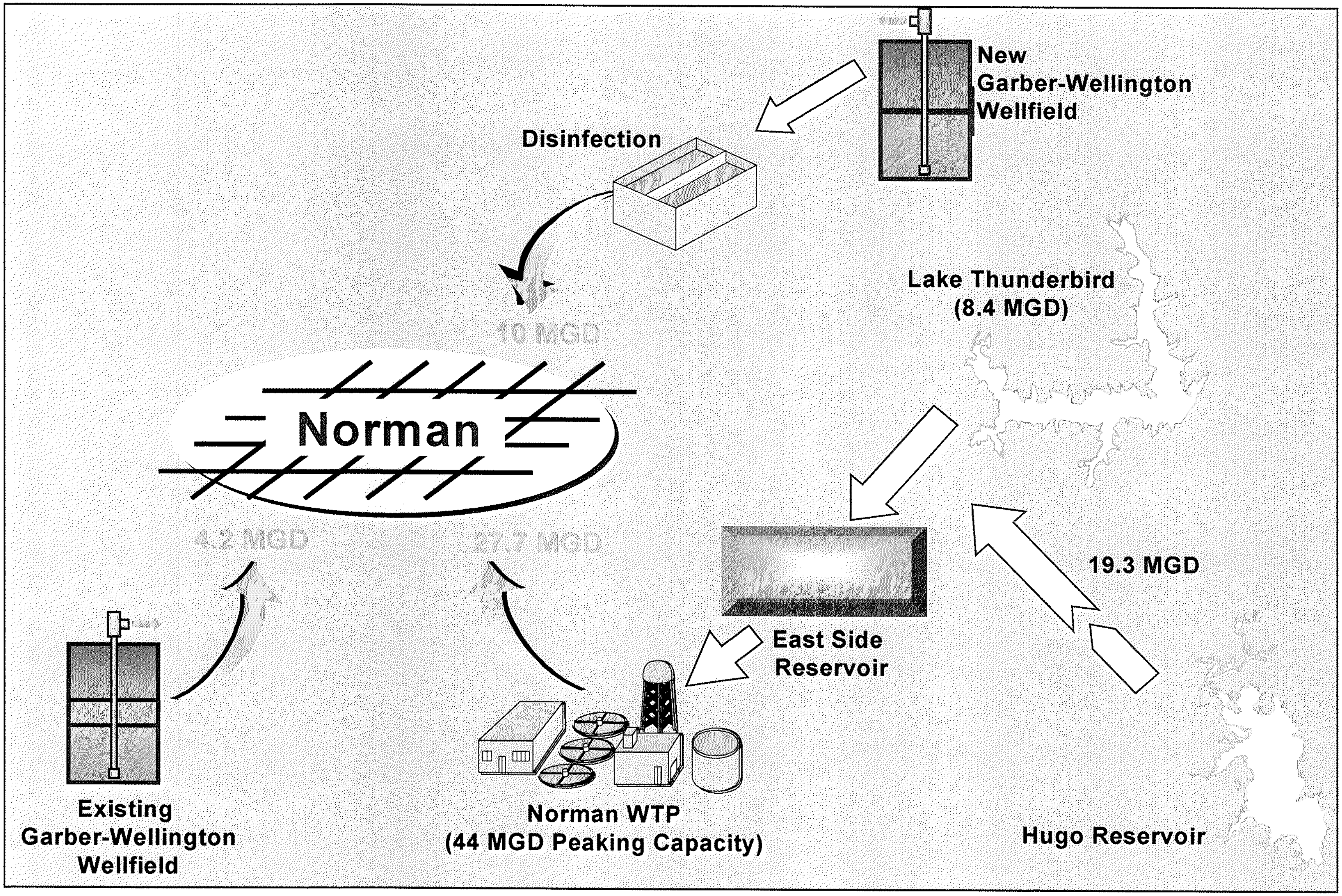


FIGURE 3-22
Norman Strategic Water Supply Plan
Plan Alternative D

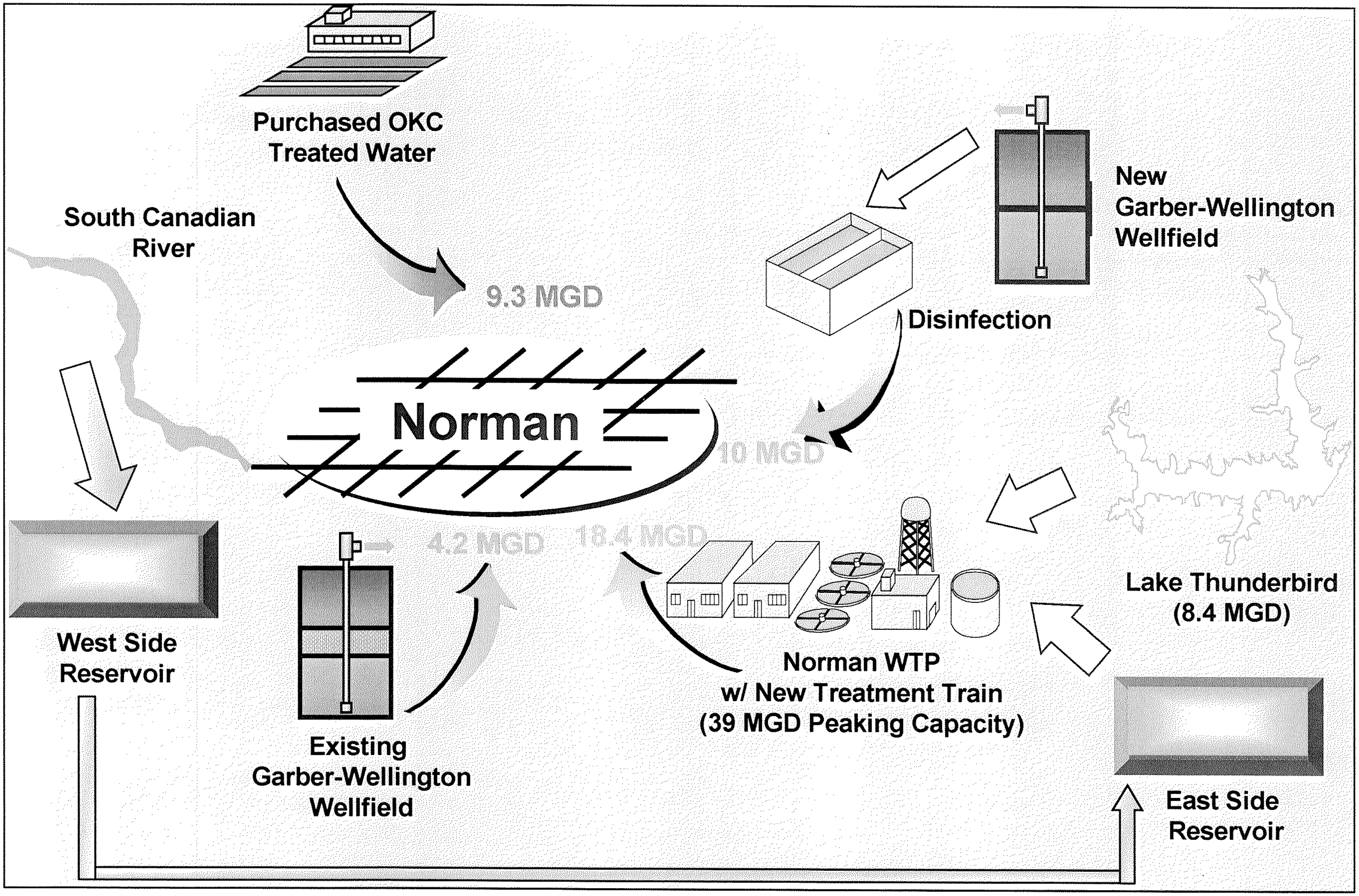


FIGURE 3-23
Norman Strategic Water Supply Plan
Plan Alternative E

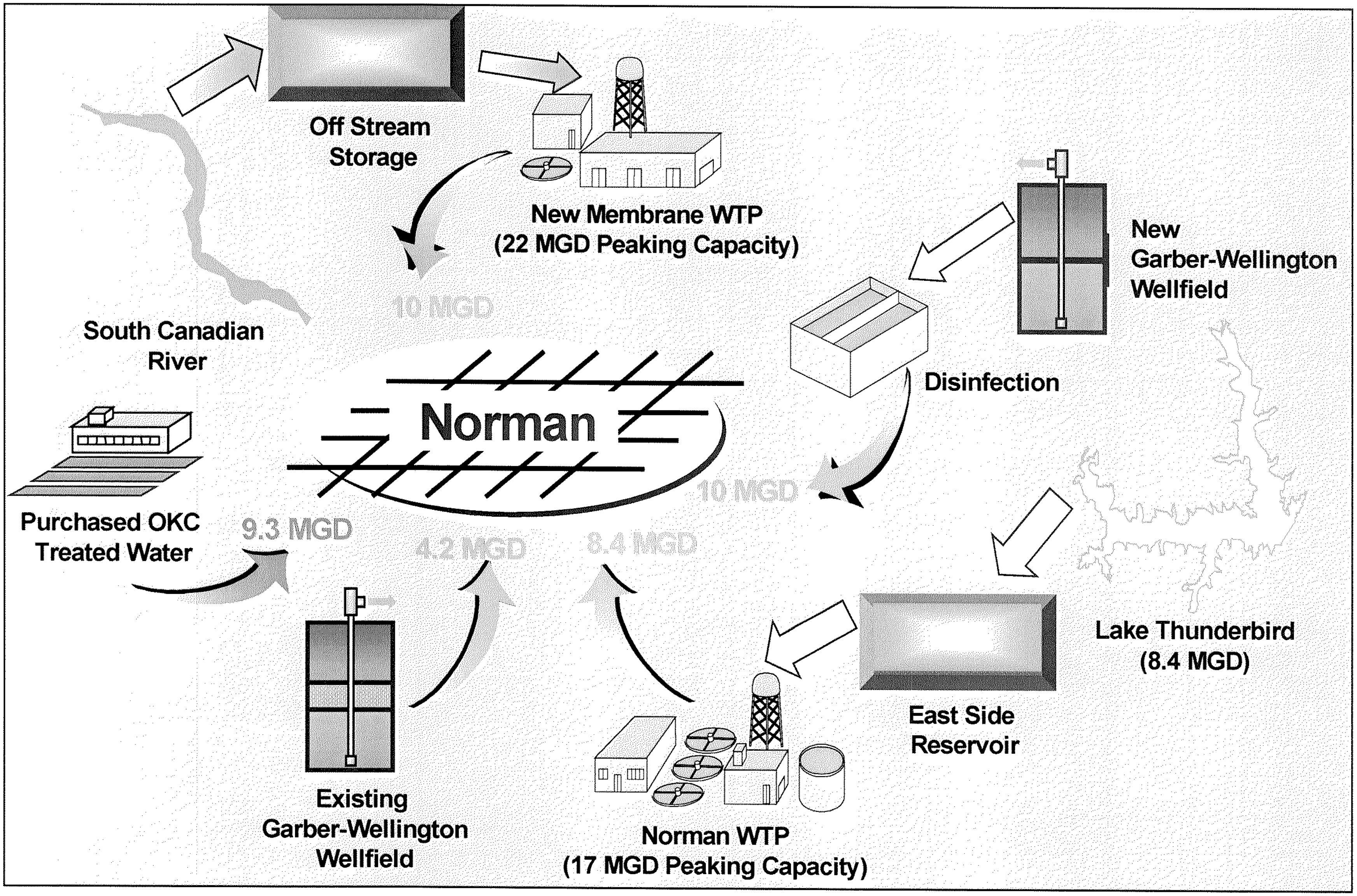


FIGURE 3-24
Norman Strategic Water Supply Plan
Plan Alternative F

Monetary Evaluation

Monetary evaluation of the Plan Alternatives involves relative comparison of capital cost, annual O&M costs, and a 40-Year total present worth. Present-worth analysis was completed assuming a 5 percent interest rate and a 3 percent inflation rate, for an effective interest rate of 2 percent over the 40-year planning horizon. Table 3-52 presents a summary of the total costs for each plan alternative. Detailed cost compilations for each Plan Alternative are provided in Appendix C.

TABLE 3-52
Strategic Water Supply Plan Alternatives
40-Year Present Worth (X $1 M)

Plan Alternative	A	B	C	D	E	F
Capital	20	35	80	174	109	111
O&M	335	218	196	160	175	179
Total	355	253	276	334	284	290

As evidenced by Table 3-52, there is great variability between capital and O&M costs. Costs attributable to new infrastructure are classified as capital. Whereas, costs associated with power, chemical, labor, and contract purchase of treated or raw water (as is the case with the OKC options) are classified as O&M. The summation of theses capital and O&M costs over the planning horizon and brought back to current equivalent cost is that value reported as total present worth. This explains why an alternative with negligible new infrastructure needs can have a higher total present worth than an alternative with significant infrastructure needs. This is demonstrated by the fact that the Do Nothing (Plan A) Alternative has a similar total present worth as the Lake Hugo (Plan D) Alternative.

Notably, planning horizon finished water distribution system capital and O&M costs were not included in this evaluation. Such costs will inevitably contribute to the total cost of any one of the six plan alternatives. The City initiated a water distribution study in the spring of 2001 to develop distribution capital needs and associated costs for the selected Strategic Water Supply Plan.

Non-Monetary Evaluation

Non-monetary evaluation criteria were identified at project outset and refined during a series of project workshops with City staff. These criteria were used to assess the non-monetary relative value of each Plan Alternative. Identified non-monetary factors are ranked in the following order of importance.

- **Public Acceptance** –Public acceptance is critical for the implementation of any plan. A primary goal for public acceptance is development of a safe, reliable, and independent water supply system for the citizens of Norman.

- **Water Quality and Compatibility** – The new plan must include the best available raw water quality with treatment options that are compatible with the existing facilities and distribution system.
- **Water Rights** – Water rights are an important issue, and the City would like to hold water rights to the future source that is recommended.
- **Environmental Impacts** – The plan should minimize environmental impacts such as extreme land use changes (reservoir and pipeline construction).
- **Reliability** – The water resources yield must be secure for the planning horizon and not subject to reduction or loss.
- **Implementability** – The plan must have the ability to be phased into connection with the existing system. This allows for ease of construction and lessens the financial burden to the City. Phasing should include short-, medium-, and long-term.
- **Future Implications** – The recommended plan must have the ability for expansion beyond the planning horizon.
- **Flexibility** – The plan should consider: potential expandability for future unforeseen demand, leverage for potential development of new water resources, and ability for meeting increasingly stringent drinking water standards.
- **Redundancy** – The plan should include some element of redundancy in the event that a source becomes temporarily unreliable due to drought or regulation.

Relative ranking of the Plan Alternatives with respect to each of the eight non-monetary criteria was performed during project workshop forums. Forum participants included citizens of Norman and City staff from the departments of Utilities, Public Works, Planning, and Financial. Furthermore, insight for the non-monetary evaluation was gained during presentations to City officials, which were open to the media and public. The results of the non-monetary evaluation are revealed in Table 3-53.

Evaluation Summary

Plan A has the highest total present worth of the six plans evaluated. With the exception of improvements to the existing raw water conveyance system from Lake Thunderbird to the existing WTP, this plan offers the City a "do nothing" alternative with respect to capitalization of major water supply and treatment infrastructure. However, due to heavy reliance on OKC for source supply, the largest single cost component associated with Plan A is the purchase of water from OKC. Such reliance would greatly reduce the negotiating leverage in the future, and hence limit the potential to develop a more cost-effective water supply source in the future through sole initiation or partnerships. Due to this lack of flexibility and because the City would not gain water rights of the water source, this plan also has the lowest non-monetary standing of the six plans.

Plan B maximizes the use of the City's most cost-effective water supply source to decrease reliance on water purchased from OKC. Similar to Plan A, improvements are required at the existing Lake Thunderbird raw water conveyance system. This plan also develops a new GWA wellfield to use the groundwater currently available within the City. As such, this

Table 3-53
City of Norman Strategic Water Supply Plan
Non-Monetary Evaluation

Plan	Non-Monetary Evaluation Ranking: 1 = most favorable ; 6 = least favorable									
	Non-Monetary Factors									
	Public Acceptance	Water Quaity and Compatibility	Water Rights	Environmental Impacts	Reliability	Implementability	Flexibility	Redundancy	Ranking Summaion	Final Non-Monetary Ranking
A	6	4	6	1	5	1	6	6	35.0	6
B	5	3	5	2.5	6	2	5	5	33.5	5
C	2.5	1.5	4	2.5	2	3	2	3	20.5	1
D	1	1.5	1	6	1	6	3	2	21.5	2
E	2.5	5	2	5	3.5	5	1	1	25.0	3
F	4	6	3	4	3.5	4	4	4	32.5	4

[1] Annual inflation is assumed at 3 percent per annum.

[1] Consistent with rate-making methodology, rate increases over the life of the utility are set to recover operations costs but should also be sufficient to generate additional revenues to sustain long-term funding efforts.

plan offers the least total present worth of all plans. However, this plan assumes the same potential flaw as Plan A and ranks fifth based on non-monetary factors. Heavy reliance on purchased treated water from OKC in the long-term greatly reduces the City's latitude in gaining ownership of a new and potentially more cost-effective water supply source in the future.

With Plan C and all subsequent plan alternatives, the expanded wellfield is coupled with a new raw water resource requiring implementation of raw water conveyance and treatment facilities. With such development, the City retains control of the water system infrastructure drivers—capacity, replacement, and quality. Infrastructure is put in place to meet the City's water demands, take advantage of existing resources and facilities, and align the City to capture potentially more cost-effective supply sources in the future.

Plan C includes OKC raw water purchase with diversion to Lake Thunderbird and a new terminal reservoir that is part of the existing raw water conveyance system improvements. Both Lake Thunderbird and OKC-purchased raw water would be conveyed to the existing WTP. The existing WTP capacity would be expanded by 27 mgd to a Year 2040 capacity of 44 mgd. Furthermore, the raw water conveyance system would be expanded to support WTP production. Of the six plans, Plan C has the second lowest present worth and ranks first non-monetarily. Such favorable rankings are largely due to this plan taking full advantage of the City's existing resources and infrastructure to meet water demands, while best positioning the City to potentially acquire ownership of a new resource over the planning horizon or beyond and without extreme capital needs for implementation of extensive infrastructure.

Plan D incorporates similar capital projects included in Plan C with expansion to the Lake Thunderbird raw water conveyance system and a 27-mgd capacity expansion of the WTP. However, the City would transition from OKC raw water supply to Hugo Reservoir in the long term. Plan D has the second highest total present worth, with raw water conveyance infrastructure from Southeast Oklahoma to Norman being a major cost component. Although, this is the only plan of the six that provides the City with full ownership of resources that exceed the Year 2040 water demands. Thus, Plan D ranks second non-monetarily.

Development of the South Canadian River with appropriately sized off-stream storage reservoirs and treatment facilities are the major components of Plan E and F. Plan E includes capturing and conveying raw water supply from the South Canadian River to a west-side terminal reservoir when river flows are sufficient to support such a practice. Raw water from the west-side reservoir would be conveyed to an east-side reservoir in close proximity to the existing Norman WTP. The existing Norman WTP would be expanded with a new 22-mgd membrane treatment train dedicated to the South Canadian River raw water supply. Plan F is similar to Plan E except one westside reservoir would be implemented for off-stream storage of raw water from the South Canadian River. A new membrane Westside WTP would treat the water supply from the reservoir prior to distribution.

Development of the South Canadian River, which is a water resource directly adjacent to the City, reduces infrastructure and O&M costs as compared to development of Southeast Oklahoma resources. As such, the total present worth of Plan E and F, respectively, are the third and fourth lowest of the six plans. Of the two Plan E is monetarily comparable to

Plan C. Although comparable, sensitivity to relatively poor raw water quality and implementation issues cast Plan E as well Plan F in less favorable light non-monetarily when compared to Plan C. Table 3-54 presents the matrix analysis results of the Plan Alternatives monetary and non-monetary evaluations.

TABLE 3-54
City of Norman Strategic Water Supply Plan
Matrix Analysis

	Matrix Analysis Ranking: 1 = most favorable ; 6 = least favorable			
	Factors			
Plan	Monetary	Non-Monetary	Ranking Summation	Final Ranking
A	6	6	12	**6**
B	1	5	6	**3**
C	2.5	1	3.5	**1**
D	4.5	2	6.5	**4**
E	2.5	3	5.5	**2**
F	4.5	4	8.5	**5**

3.4.4 Recommended Plan Alternative

As the matrix analysis indicates, Plan C appears most favorable. In order to further ascertain the plan that is best suited to the needs and objectives of the City, a sensitivity analysis was conducted for the plans ranking monetarily closest to Plan C. As indicated in Table 3-54, the monetary component of Plan B is most attractive. However, consideration should be given to the potential implications associated with the lack of ownership in a water supply source—OKC-purchased treated water—that contributes 46 percent of Year 2040 targeted demand. Such reliance greatly limits the City's control of the water system. Plan E is monetarily comparable to Plan C and curtails a large portion of the uncertainty of the reliance on purchase of treated water. However, water quality, potential negative environmental impacts, and implementation issues associated with the South Canadian River offers a similar unappealing position.

Conversely, Plan C includes development of the City's most cost-effective water supply source, the GWA, and addresses the reliance on purchased OKC-treated water. Under Plan C, the City would retain control of water quality and capacity of finished water through expansion of the raw water conveyance system and WTP. The raw water conveyance system expansion includes a new terminal reservoir in eastern Norman, between Lake Thunderbird and the WTP. Thus, terminal storage, conveyance, and treatment capacity would be implemented to allow the City to capitalize on "bonus" water from Lake Thunderbird under-utilized Midwest City and Del City yield, flood control pool, and/or potentially reallocated conservation pool. Additionally, this infrastructure provides the City with flexibility and leverage to develop a partnership in developing a water resource in Southeastern Oklahoma, if and when such a partnership comes to fruition. This flexibility is warranted considering the recent interest in the three water resources in the Kiamichi River Basin—Sardis Reservoir, Kiamichi River, and Lake Hugo—by communities in Central Oklahoma. Therefore, Plan C is recommended as the preferred water supply plan to meet the City's water system needs through the 40-year planning horizon. Short-, mid-, and long-term supply source details for Plan C are presented on Figure 3-25.

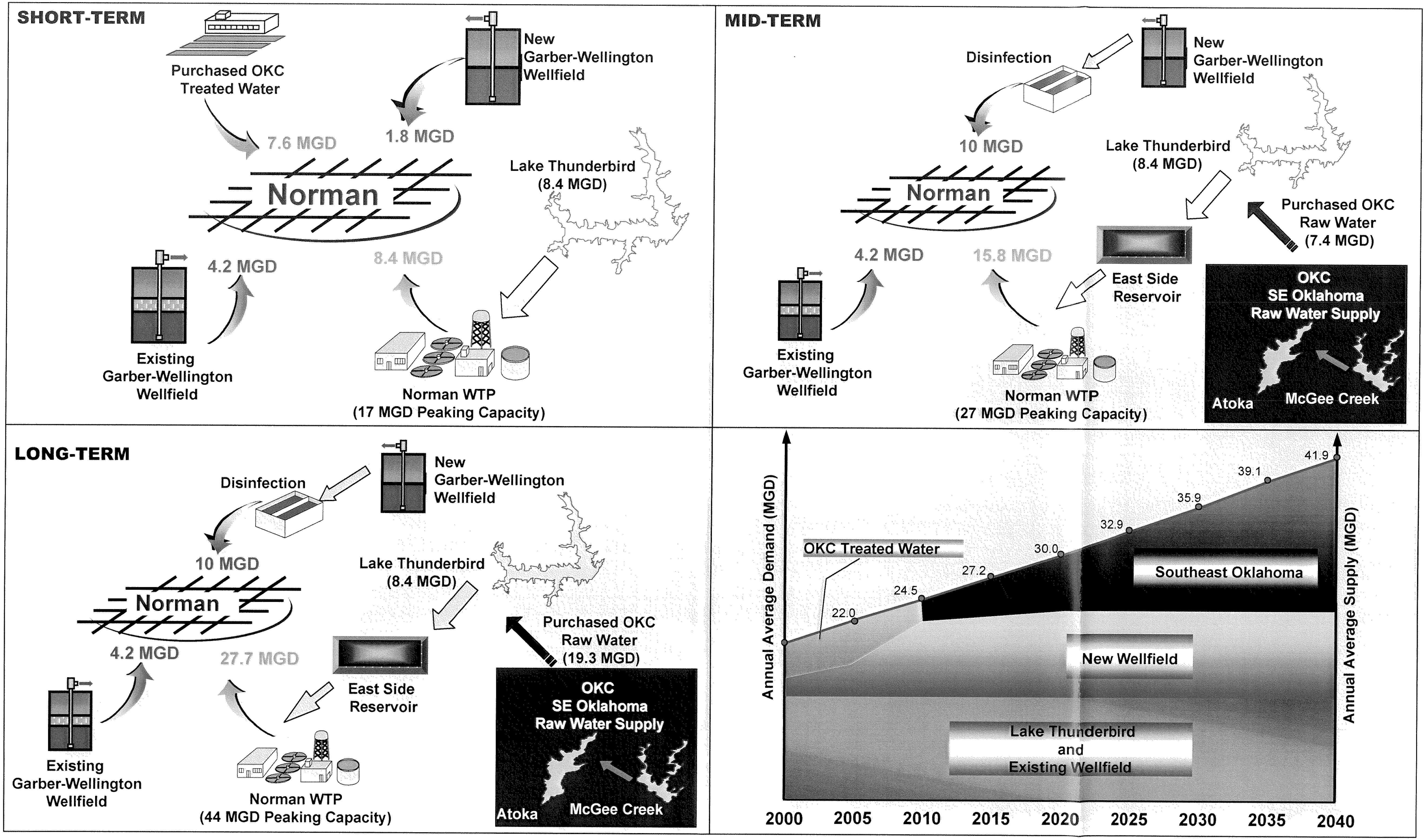


FIGURE 3-25
Recommended Strategic Water Supply Plan
Plan Alternative C - Southeast Oklahoma

4. Plan Development

4.1. Capital Outlay Plan

To assist the City Finance Department, a capital outlay schedule for the recommended water supply plan was developed. For the capital outlay plan, consideration was given to staging projects to allow each water resource and associated production/treatment subsystem to meet the projected water demands. For each treatment subsystem, the implementation period was identified and coupled with the demand projections to help identify staging requirements. Table 4-1 provides the capital outlay schedule for the recommended water supply plan (Plan C). The following paragraphs describe the logic behind the capital outlay schedule for each component of the recommended water supply plan.

4.1.1. Expanded Wellfield

The capital outlay plan for the expanded wellfield includes costs associated with 30 new well facilities including water rights and land purchase, wellhead, well house, and pumping units. Regarding water rights for the planned 30 additional wellheads, it was assumed that a one-acre parcel would be purchased at each wellhead site. Existing City-owned groundwater rights within the Corporate boundary would be dedicated to the planned development sites. This approach reflects similar permitting by OWRB in the past. State legislature was being developed at the time of this writing to uphold this historical OWRB permitting practice.

As the expanded wellfield is proposed in the unconfined portion of the Garber-Wellington, a new, common, disinfection facility is included for these wells. In addition, water transmission piping associated with the wellhead alignment identified in Section 3, Alternatives Evaluation, is included to convey well water from the wellheads to the disinfection facility. To this end, wellhead placement and hence the piping schedule is considered for the western portion of the proposed wellfield first, with systematic placement to the east with each stage of development.

The disinfection facility is staged with the Phase I expansion of the WTP. The groundwater disinfection facility is directly dependent on water quality, as compared to the criteria of the Safe Drinking Water Act (discussed in Section 2). To address the uncertainty of water quality from the wells implemented prior to the disinfection facility, transmission piping is scheduled for implementation that routes the flow by the existing WTP. If poor water quality becomes an issue that warrants treatment, treatment could be provided with existing facilities at the WTP until the groundwater treatment facility is brought online.

For the short term (first five years), one well per year is scheduled for development along with one set of monitoring wells starting in Year 2001. Following development of the first five wells and monitoring of the aquifer, a more aggressive implementation schedule is proposed for the next five years based on the targeted water demand. Considering the time

Table 4-1

Norman Strategic Water Supply Plan

Capital Outlay Schedule

Capital Project	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2030	2031	2032	2033	2034	2035	2040	Total
	Recommended Strategic Water Supply Plan - Plan C Cost (x 1,000) [a], [b]																																
	Short-Term					*Mid-Term*															*Long-Term* [e]												
New Wellfield																																	
Land Purchase	$ 25				$ 75					$ 25					$ 25																		$ 150
Production Wells	$ 190	$ 190	$ 190	$ 190	$ 190	$ 570	$ 570	$ 570	$ 570	$ 570	$ 190	$ 190	$ 190	$ 190	$ 190	$ 190	$ 190	$ 190	$ 190	$ 190													$ 5,700
Monitoring Wells	$ 16					$ 16						$ 16																					$ 48
Piping [c]	$ 456	$ 304	$ 507	$ 608	$ 1,419	$ 1,166	$ 507	$ 558	$ 456	$ 507	$ 456		$ 203			$ 203																	$ 7,350
Disinfection Facility [c], [d]								$ 208	$ 1,247	$ 623																							$ 2,078
Subtotal																																	**$ 15,326**
Terminal Reservoir																																	
Land Purchase	$ 1,080																																$ 1,080
Reservoir Construction [d]				$ 983	$ 5,896	$ 2,948																											$ 9,827
Pump Station Expansion (17 mgd) [d]																						$ 76	$ 454	$ 227									$ 757
Subtotal																																	**$ 11,664**
Raw Water Conveyance																																	
OKC Diversion Structure									$ 250																								$ 250
Phase I WTP Raw Water Line [d]					$ 611	$ 3,666	$ 1,833																										$ 6,110
Phase II WTP Raw Water Line [d]							$ 380	$ 2,278	$ 1,138																								$ 3,796
Subtotal																																	**$ 10,156**
WTP																																	
Phase I Expansion (10 mgd) [d]								$ 1,590	$ 9,540	$ 4,770																							$ 15,900
Phase II Expansion (10 mgd) [d]																						$ 1,590	$ 9,540	$ 4,770									$ 15,900
Phase III Expansion (7 mgd) [d]																												$ 1,154	$ 6,922	$ 3,461			$ 11,537
Subtotal																																	**$ 43,337**
Total	**$ 1,767**	**$ 494**	**$ 697**	**$ 1,781**	**$ 8,191**	**$ 8,366**	**$ 3,290**	**$ 5,204**	**$ 13,201**	**$ 6,495**	**$ 646**	**$ 206**	**$ 393**	**$ 190**	**$ 215**	**$ 393**	**$ 190**	**$ 190**	**$ 190**	**$ 190**	**$ -**	**$ 1,666**	**$ 9,994**	**$ 4,997**	**$ -**	**$ -**	**$ -**	**$ 1,154**	**$ 6,922**	**$ 3,461**	**$ -**	**$ -**	**$ 80,483**

Notes:

[a] All costs are Year 2000 Present Worth

[b] Capital Outlay Plan does not include O&M costs (i.e., wholesale purchase of OKC raw or treated water)

[c] Project is directly related to the new wellfield (i.e., water quality and wellhead alignment).

[d] Facility construction costs are allocated based on 10, 60, and 30 percent expenditure for the 1st, 2nd, and 3rd year, respectively.

[e] Capital projects allocated to only the years shown.

frame for engineering services, siting well locations, drilling, and construction, the capital outlay schedule assumes that three wells per year will be implemented in this time frame. Additionally, a second set of monitoring wells is scheduled for completion. This considered, 20 new wells and two sets of monitoring wells are planned to be online in Year 2010.

Continued aquifer monitoring and development of one well per year (including a third set of monitoring wells) is proposed following Year 2010. As such, all 30 new wells and three sets of monitoring wells are scheduled for completion in the short- and mid-term (Year 2001 through 2020). In all cases, land purchase is scheduled on a five-year interval based on the number of wells proposed for completion.

4.1.2. Terminal Reservoir

As part of the improvements to the existing Lake Thunderbird raw water conveyance system, a new terminal reservoir is proposed in eastern Norman. This reservoir would more readily allow phased improvements and expansion to the raw water conveyance pipeline, plus provide storage for the City to capture "bonus" water from Lake Thunderbird. Bonus water includes taking advantage of Midwest City's and Del City's under-utilized allocation and/or captured supply from the flood control pool. This additional supply would augment the City's current Lake Thunderbird allocation, allowing water demands to be satisfied to a greater extent with treated Lake Thunderbird water. Furthermore, this reservoir would provide storage for conveying a new raw water resource in Southeast Oklahoma, if such a project should develop in the long term or beyond the planning horizon.

For implementation, land purchase dedicated to the new terminal reservoir is scheduled for 2001. Construction of the terminal reservoir is scheduled on the timeline for purchasing raw water from Oklahoma City coupled with expansion to the conveyance system and WTP. Reservoir construction is scheduled to begin in 2004, with completion in 2006. This schedule allows time for reservoir filling and settling before the expanded WTP is brought online. Within this time frame, the raw water conveyance system expansion and the Oklahoma City raw water diversion structure are also scheduled for completion. Thus, Lake Thunderbird bonus water as well as Oklahoma City raw water will be available to support the terminal reservoir.

The pumping facility at the reservoir is proposed to match the phased implementation of the WTP. Thus, a 27-mgd capacity pumping station is proposed initially for construction at the reservoir to serve the existing WTP and the first WTP-expansion project. For the long term, a pumping facility expansion to 44 mgd is proposed to match the second and third WTP-expansion phases.

4.1.3. Raw Water Conveyance System

Capital improvements to the raw water conveyance system include upgrades to the existing raw water pump station and conveyance pipeline so that conveyance capacity is expanded to match the planned 44-mgd WTP production capacity. Since the existing raw water pump station and pipeline are owned and operated by COMCD, it is reasonable to believe the City will not be required to carry the full capital funding burden for upgrade and expansion of the raw water conveyance system. Nevertheless, a conservative approach has been assumed wherein the full capital costs for these improvements are included in the capital outlay plan. Any savings realized through COMCD will strengthen the recommended plan.

As conceived, the new 42-inch pipeline would serve both the terminal reservoir and the WTP. Improvements are scheduled in two phases. Each phase includes one of two pipeline segments—from Lake Thunderbird to the terminal reservoir or from the terminal reservoir to the WTP. Although the order of implementation is virtually interchangeable, the capital outlay plan has been developed with the Lake Thunderbird to the terminal reservoir segment being implemented first. This approach will most readily facilitate filling of the new terminal reservoir.

The first phase includes implementing new, higher-capacity pumping units at the pump station to match WTP production capacity and provide capacity to support the new terminal reservoir. Coinciding with the pumping units improvements is a new 42-inch raw water conveyance line from Lake Thunderbird to the terminal reservoir. Additionally, this line would connect with the existing conveyance line at the reservoir diversion point to serve the WTP. Thus, the new pumping units and conveyance line could support both the WTP and the reservoir. Considering the critical dependence of the WTP on the conveyance line, the most probable approach for constructing the new conveyance line would be parallel construction with the existing line. After the new line is in place and operational, the existing line could be abandoned. Abandonment is assumed for the 40-year capital outlay plan based on the age and questionable condition of the existing line.

As scheduled, the second raw water conveyance system segment would be initiated as the first phase enters the final stages of completion. The second phase includes continuing the new 42-inch pipeline from the reservoir diversion point to the WTP. With this line segment completed, the WTP could receive raw water from Lake Thunderbird, the terminal reservoir, or both. With greater raw water conveyance capacity, the existing WTP production capacity could be increased upwards of 17 mgd as needed to meet water demands in the Year 2008. To support increased production to meet the targeted water demands, the Oklahoma City raw water diversion structure is scheduled for Year 2009. Thus, Lake Thunderbird and Oklahoma City raw water would be available by Year 2010 to support the maximum production capacity of the existing WTP. As discussed in the following paragraphs, the WTP capacity would need to be expanded by Year 2011 to satisfy the mid- and long-term water demands.

4.1.4. Water Treatment Plant

Based on the projected water production planning curve for the 40-year planning horizon, the WTP would need to be expanded from 17-mgd peak production capacity to a rated capacity of 44 mgd. With full consideration to the proposed new wellfield development schedule, this expansion is proposed in three phases. The first phase includes a 10-mgd expansion component. This expansion component, coupled with existing facilities and the new wellfield, would serve the City until Year 2025. Typical WTP capital improvements target a minimum 10-year incremental capacity interval to meet water demands. The first WTP expansion phase of 10 mgd effectively provides a 14-year capacity interval. The existing WTP has a rated capacity of 14 mgd, although more than likely the plant can treat upwards of 17 mgd. The first-phase expansion would address any components, if needed, that could not reliably meet the 17-mgd production capacity. Additionally, this expansion component provides flexibility for developing the new wellfield. Furthermore, capacity would be in place to serve additional raw water captured from Lake Thunderbird. The second and third phases will expand the WTP by 10 mgd and 7 mgd, respectively. As such, the second phase would expand the WTP to 37 mgd by Year 2025; whereas, the third phase will expand the WTP from 37 mgd to 44 mgd by Year 2035.

4.2. Financial Impacts Analysis

This section presents an overview of assumptions of the financial analysis, capital financing options, and resulting debt service schedules for the planning period 2001-2040.

4.2.1. Capital

Based on the proposed water master plan, the inflated Capital Improvements Plan (CIP) will require approximately $129.4 million[1] ($80.5 million in 2000 dollars) in total funding over the forecast period, as discussed previously. The present worth and inflated capital outlay schedules are provided in Appendix D Tables D-1 and D-2, respectively. Following a brief transition period, the majority of system improvements are planned in the implementation window before Year 2020. Only the second and third phases of the WTP expansion, as well as required pumping facilities at the reservoir, are scheduled for the latter half of the 40-year schedule. Besides capital costs associated with the new wellfield, most capital projects assume construction draws in three-year increments of 10, 60, and 30 percent of the total project cost, respectively.

4.2.2. Funding Scenarios

Two funding scenarios have been developed to demonstrate financing alternatives.

- Scenario 1: Assumes projects are 100 percent debt funded
- Scenario 2: Capital costs will be financed through a combination of cash reserves from the operating fund and debt

Under both scenarios, interest earned on debt proceeds will account for some project funding. Each scenario also makes use of three different types of debt instruments: Oklahoma Water Resource Board (OWRB) Promissory Notes, State Revolving Fund (SRF) Loans, and Revenue Bonds. Debt service schedules are calculated based on the following assumptions.

1. State OWRB Promissory Note

Interest rate	4.25%
Annual finance cost	0.5%
Term	Construction Period

[1] Annual inflation is assumed at 3 percent per annum.

2. **State Revolving Fund Loan**

Interest rate	0.0%
Annual finance cost	0.5%
Reserve requirement	0.0%
Term	20 years

3. **Revenue Bonds**

Interest rate	6.16%
Finance cost	3.25%
Reserve requirement	7.39% (equal to one payment)
Term	30 years

Consistent with construction draws, financing is considered in three-year increments. For each of these increments, an OWRB promissory note is issued in the first year of the financing period and annual payments are made during the construction period. The year following completion of construction, the promissory note is repaid through a combination of proceeds from an SRF loan and a revenue bond.

Scenario 1

Under this scenario, capital projects would be funded strictly by a combination of debt proceeds and interest earned in the construction fund. Table 4-2 indicates the number and sizing for each of the three debt instruments required to provide adequate funding for construction draws. Detailed funding and debt service schedules for Scenario 1 are provided in Appendix D Table D-3. With a few minor exceptions, four principal financing periods are considered: 2005, 2008, 2022, and 2032. For each of these periods, construction is funded with OWRB notes issued in the year construction begins. In 2005, sizing of the OWRB note is $23 million; in 2008 and 2022, $31 million; and in 2032, $29 million. After construction, 40 percent of each OWRB note is repaid with proceeds from an SRF loan, and 60 percent is repaid using proceeds from a revenue bond. Debt service schedules are calculated based on debt financing assumptions, which were outlined earlier in this section.

In addition to the four major financing increments, a $5 million revenue bond is issued in 2001 to cover CIP expenditures for the first four years of the forecast and another $3 million is added to the 2011 revenue bond issue to support various improvements associated with the new wellfield until the second phase of the WTP expansion begins in 2022.

Because each three-year financing period involves the issuance of 3 distinct debt instruments, the number of debt issues totals 13. Annual debt service payments fluctuate between $0.4 million in 2001 and $7.2 million in 2035. The average-annual debt service payment over the forecast period is approximately $4.6 million.

Table 4-3 shows a summary of funding sources. Of the $129 million in planned CIP expenditures, $114 million would be funded with proceeds from OWRB notes. SRF loans would provide $45.6 million (35 percent of funding), and revenue bonds would provide $68.4 million (52.5 percent of funding) to repay OWRB notes. Revenue bond amounts in addition to those dedicated for repayment of OWRB notes would total $8 million (6.2 percent of funding). Interest earned in the construction fund is expected to generate roughly $8.2 million (6.3 percent of funding). Debt service payments over the 40-year period

Table 4-2

Norman Strategic Water Supply Plan

Financial Impacts Analysis: Scenario No. 1 - Funding and Debt Service Summary

Component	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Beginning Balance	$ -	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,132,748	$ 2,988,336	$ 2,546,190	$ 2,378,923
CIP	$ 1,820,010	$ 524,085	$ 761,631	$ 2,004,531	$ 9,495,614	$ 9,989,442	$ 4,046,285	$ 6,592,272	$ 17,224,311	$ 8,728,737	$ 894,215	$ 293,707	$ 577,134	$ 287,392	$ 334,963
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000,000	$ -	$ -	$ 31,000,000	$ -	$ -	$ -	$ -
OWRB Notes	$ -	$ -	$ -	$ -	$ 23,000,000	$ -	$ -	$ 31,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9,200,000	$ -	$ -	$ 12,400,000	$ -	$ -	$ -	$ -
Revenue Bonds	$ 5,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,800,000	$ -	$ -	$ 21,600,000	$ -	$ -	$ -	$ -
Interest on Fund	$ 79,500	$ 149,872	$ 125,223	$ 62,330	$ 352,943	$ 458,464	$ 130,494	$ 646,055	$ 857,943	$ 252,014	$ 99,041	$ 149,295	$ 134,988	$ 120,125	$ 110,572
TOTAL	$ 5,079,500	$ 149,872	$ 125,223	$ 62,330	$ 23,352,943	$ 458,464	$ 130,494	$ 54,646,055	$ 857,943	$ 252,014	$ 34,099,041	$ 149,295	$ 134,988	$ 120,125	$ 110,572
Ending Balance	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,132,748	$ 2,988,336	$ 2,546,190	$ 2,378,923	$ 2,154,532
Debt Service Schedule	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 1,501,297	$ 1,501,297	$ 1,501,297	$ 3,515,577	$ 3,515,577	$ 3,515,577	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081

Component	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Beginning Balance	$ 2,154,532	$ 1,615,843	$ 1,374,743	$ 1,111,931	$ 826,032	$ 515,594	$ 541,374	$ 29,071,409	$ 10,307,855	$ 411,429	$ 432,000	$ 453,600	$ 476,280	$ 500,094	$ 525,099
CIP	$ 630,650	$ 314,041	$ 323,462	$ 333,166	$ 343,161	$ -	$ 3,192,228	$ 19,724,024	$ 10,157,872	$ -	$ -	$ -	$ -	$ -	$ -
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 31,000,000	$ -	$ -	$ -	$ -	$ -
OWRB Notes	$ -	$ -	$ -	$ -	$ -	$ -	$ 31,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SRF Loans	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,400,000	$ -	$ -	$ -	$ -	$ -
Revenue Bonds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 18,600,000	$ -	$ -	$ -	$ -	$ -
Interest on Fund	$ 91,960	$ 72,941	$ 60,651	$ 47,267	$ 32,723	$ 25,780	$ 722,263	$ 960,470	$ 261,446	$ 20,571	$ 21,600	$ 22,680	$ 23,814	$ 25,005	$ 26,255
TOTAL	$ 91,960	$ 72,941	$ 60,651	$ 47,267	$ 32,723	$ 25,780	$ 31,722,263	$ 960,470	$ 261,446	$ 31,020,571	$ 21,600	$ 22,680	$ 23,814	$ 25,005	$ 26,255
Ending Balance	$ 1,615,843	$ 1,374,743	$ 1,111,931	$ 826,032	$ 515,594	$ 541,374	$ 29,071,409	$ 10,307,855	$ 411,429	$ 432,000	$ 453,600	$ 476,280	$ 500,094	$ 525,099	$ 551,354
Debt Service Schedule	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 5,963,581	$ 5,963,581	$ 5,963,581	$ 6,693,807	$ 6,693,807	$ 6,693,807	$ 6,187,807	$ 6,187,807	$ 5,779,009

Component	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Beginning Balance	$ 551,354	$ 578,922	$ 27,286,931	$ 9,832,827	$ 632,966	$ 664,614	$ 697,845	$ 732,737	$ 769,374	$ 807,843
CIP										
OWRB Repayment	$ -	$ 2,971,646	$ 18,359,465	$ 9,455,124	$ -	$ -	$ -	$ -	$ -	$ -
	$ -	$ -	$ -	$ -	$ 29,000,000	$ -	$ -	$ -	$ -	$ -
OWRB Notes										
SRF Loans	$ -	$ 29,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Revenue Bonds	$ -	$ -	$ -	$ -	$ 11,600,000	$ -	$ -	$ -	$ -	$ -
Interest on Fund	$ -	$ -	$ -	$ -	$ 17,400,000	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 27,568	$ 679,655	$ 905,360	$ 255,263	$ 31,648	$ 33,231	$ 34,892	$ 36,637	$ 38,469	$ 40,392
	$ 27,568	$ 29,679,655	$ 905,360	$ 255,263	$ 29,031,648	$ 33,231	$ 34,892	$ 36,637	$ 38,469	$ 40,392
Ending Balance	$ 578,922	$ 27,286,931	$ 9,832,827	$ 632,966	$ 664,614	$ 697,845	$ 732,737	$ 769,374	$ 807,843	$ 848,235
Debt Service Schedule	$ 5,097,009	$ 6,474,509	$ 6,474,509	$ 6,474,509	$ 7,157,623	$ 7,157,623	$ 6,029,343	$ 6,029,343	$ 6,029,343	$ 4,263,340
Average DS Payment	**$ 4,585,041**									

total $183.4 million. Whereas, debt service payments over the entirety of the debt service periods total $247.6 million.

TABLE 4-3
Norman Strategic Water Supply Plan
Financial Impact Analysis: Scenario No. 1 (Debt Funded) - Summary

Inflated Capital Improvement Program		**$ 129,379,165**	
Funding Sources	**OWRB Repay**		**% of Total**
OWRB Promissory Notes		114,000,000	
SRF Loans (Repayment of OWRB)	45,600,000		35.0%
Revenue Bonds (Repayment of OWRB)	68,400,000		52.5%
Revenue Bonds (Other)		8,000,000	6.2%
Interest in the Construction Fund		$ 8,227,400	6.3%
TOTAL (Source of Funds):		**$ 130,227,400**	100%
Total Debt Service Payments (40 year window)		$ 3,401,643	
Other Funding Sources		$ -	
Combined Impact on Revenues (40 year window)		**$ 183,401,643**	
Total Debt Service Payments over time		$ 247,551,199	

Scenario 2

Scenario 2 considers using a combination of both debt and cash transfers to fund planned capital improvements. Table 4-4 analyzes the financial impact of the additional funding source on the scheduling and magnitude of debt issues. Detailed funding and debt service schedules for Scenario 2 are provided in Appendix Table D-4. Annual cash transfers are assumed to be available beginning in 2011 and are projected to slowly increase over the 40-year period. These reserves total $0.5 million in 2011 and are projected to increase to $2 million in 2015, to $2.5 million in 2019, and then to $3 million in 2033.[2] Total cash used to fund capital expenditures during this period is expected to total $52.8 million.

Using cash as an additional funding source enables the City to fund the Phase II and III plant expansion projects on a pay-as-you-go basis and eliminate subsequent debt issues beyond the first 10 years of the forecast period. As a result, individual debt issues are reduced from 13 to 7 and the average-annual debt service payment decreases from $4.6 million to $3.2 million, reflecting significant savings in costs of issuance and financing charges.

[2] Consistent with rate-making methodology, rate increases over the life of the utility are set to recover operations costs but should also be sufficient to generate additional revenues to sustain long-term funding efforts.

Table 4-4

Norman Strategic Water Supply Plan

Financial Impacts Analysis: Scenario No. 2 - Funding and Debt Service Summary

Component	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Beginning Balance	$ -	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,632,748	$ 4,263,336	$ 4,884,940
CIP	$ 1,820,010	$ 524,085	$ 761,631	$ 2,004,531	$ 9,495,614	$ 9,989,442	$ 4,046,285	$ 6,592,272	$ 17,224,311	$ 8,728,737	$ 894,215	$ 293,707	$ 577,134	$ 287,392
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000,000	$ -	$ -	$ 31,000,000	$ -	$ -	$ -
OWRB Notes	0	0	0	0	23,000,000	0	0	31,000,000	0	0	0	0	0	0
SRF Loans	0	0	0	0	0	0	0	9,200,000	0	0	12,400,000	0	0	0
Revenue Bonds	5,000,000	0	0	0	0	0	0	13,800,000	0	0	21,600,000	0	0	0
Cash (Current Revenue Financing)	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**500,000**	**750,000**	**1,000,000**	**1,500,000**
Interest on Fund	$ 79,500	$ 149,872	$ 125,223	$ 62,330	$ 352,943	$ 458,464	$ 130,494	$ 646,055	$ 857,943	$ 252,014	$ 99,041	$ 174,295	$ 198,738	$ 237,062
TOTAL	$ 5,079,500	$ 149,872	$ 125,223	$ 62,330	$ 23,352,943	$ 458,464	$ 130,494	$ 54,646,055	$ 857,943	$ 252,014	$ 34,599,041	$ 924,295	$ 1,198,738	$ 1,737,062
Ending Balance	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,632,748	$ 4,263,336	$ 4,884,940	$ 6,334,610
Debt Service Schedule	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 1,501,297	$ 1,501,297	$ 1,501,297	$ 3,515,577	$ 3,515,577	$ 3,515,577	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081

Component	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Beginning Balance	$ 6,334,610	$ 8,308,003	$ 10,076,988	$ 12,258,945	$ 14,540,343	$ 17,425,865	$ 20,445,418	$ 23,967,689	$ 24,394,040	$ 7,896,617	$ 379,629	$ 2,898,610	$ 5,543,540	$ 8,320,717
CIP	$ 334,963	$ 630,650	$ 314,041	$ 323,462	$ 333,166	$ 343,161	$ -	$ 3,192,228	$ 19,724,024	$ 10,157,872	$ -	$ -	$ -	$ -
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
OWRB Notes	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SRF Loans	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Revenue Bonds	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cash (Current Revenue Financing)	**2,000,000**	**2,000,000**	**2,000,000**	**2,000,000**	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**
Interest on Fund	$ 308,356	$ 399,634	$ 495,998	$ 604,861	$ 718,688	$ 862,714	$ 1,022,271	$ 1,118,579	$ 726,601	$ 140,884	$ 18,981	$ 144,930	$ 277,177	$ 416,036
TOTAL	$ 2,308,356	$ 2,399,634	$ 2,495,998	$ 2,604,861	$ 3,218,688	$ 3,362,714	$ 3,522,271	$ 3,618,579	$ 3,226,601	$ 2,640,884	$ 2,518,981	$ 2,644,930	$ 2,777,177	$ 2,916,036
Ending Balance	$ 8,308,003	$ 10,076,988	$ 12,258,945	$ 14,540,343	$ 17,425,865	$ 20,445,418	$ 23,967,689	$ 24,394,040	$ 7,896,617	$ 379,629	$ 2,898,610	$ 5,543,540	$ 8,320,717	$ 11,236,753
Debt Service Schedule	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 3,985,081

Component	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Beginning Balance	$ 11,236,753	$ 14,298,591	$ 17,513,521	$ 20,889,197	$ 21,387,720	$ 6,638,655	$ 279,086	$ 293,040	$ 307,692	$ 323,077	$ 339,231	$ 356,193
CIP	$ -	$ -	$ -	$ 2,971,646	$ 18,359,465	$ 9,455,124	$ -	$ -	$ -	$ -	$ -	$ -
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
OWRB Notes	0	0	0	0	0	0	0	0	0	0	0	0
SRF Loans	0	0	0	0	0	0	0	0	0	0	0	0
Revenue Bonds	0	0	0	0	0	0	0	0	0	0	0	0
Cash (Current Revenue Financing)	**2,500,000**	**2,500,000**	**2,500,000**	**2,500,000**	**3,000,000**	**3,000,000**	**0**	**0**	**0**	**0**	**0**	**0**
Interest on Fund	$ 561,838	$ 714,930	$ 875,676	$ 970,169	$ 610,399	$ 95,555	$ 13,954	$ 14,652	$ 15,385	$ 16,154	$ 16,962	$ 17,810
TOTAL	$ 3,061,838	$ 3,214,930	$ 3,375,676	$ 3,470,169	$ 3,610,399	$ 3,095,555	$ 13,954	$ 14,652	$ 15,385	$ 16,154	$ 16,962	$ 17,810
Ending Balance	$ 14,298,591	$ 17,513,521	$ 20,889,197	$ 21,387,720	$ 6,638,655	$ 279,086	$ 293,040	$ 307,692	$ 323,077	$ 339,231	$ 356,193	$ 374,003
Debt Service Schedule	$ 3,985,081	$ 3,576,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ -
Average DS Payment	**$ 3,181,109**											

Table 4-5 presents a summary of funding sources. Of the $129 million in planned CIP expenditures, $52.8 million (40.7 percent of total funding) would be paid for with cash proceeds. Another $54 million would be funded with proceeds from OWRB notes. SRF loans would provide $21.6 million (16.6 percent) and revenue bonds would provide $32.4 million (25 percent) to repay OWRB notes. Revenue bond amounts in addition to those dedicated for repayment of OWRB notes would contribute $8 million (6.2 percent) to CIP funding. Interest earned in the construction fund is expected to generate roughly $15 million (11.6 percent) of required funds.

TABLE 4-5
Norman Strategic Water Supply Plan
Financial Analysis: Scenario No. 2 (Combo Funded) - Summary

Inflated Capital Improvement Program		**$ 129,379,165**	
Funding Sources	**OWRB repay**		**% of Total**
OWRB Promissory Notes		54,000,000	
SRF Loans (Repayment of OWRB)	21,600,000		16.6%
Revenue Bonds (Repayment of OWRB)	32,400,000		25.0%
Revenue Bonds (Other)		8,000,000	6.2%
Cash used for CIP funding		$ 52,750,000	40.7%
Interest in the Construction Fund		$ 15,003,168	11.6%
TOTAL (Source of Funds):		**$ 129,753,168**	100%
Total Debt Service Payments (40 year window)		$ 127,244,351	
Total Cash Transfers		$ 52,750,000	
Combined Impact on Revenues (40 year window)		**$ 179,994,351**	
Total Debt Service Payments over time:		$ 127,244,351	

The combined impact on revenue requirements over the forecast period is reduced from $247.6 million in the first scenario to $180 million with the introduction of cash financing in the second scenario. The use of cash reserves provides balanced funding and stabilizes the debt service payment schedule. Figure 4-1 illustrates the reduction of annual debt service payments as cash is used to fund capital improvement planning.

Conclusions of the Financial Analysis

This financial analysis has presented possible funding issues and resulting debt service payments based on the proposed water supply plan capital outlay schedule. Clearly, a manageable debt schedule can be achieved to fund the plan to provide a safe, abundant, and reliable water supply to the citizens of Norman for the foreseeable 40-year horizon.

Moreover, with moderate cash financing, the Strategic Water Supply Plan debt schedule can not only be flattened but retired within the planning horizon.

Notably, revenue and cost-of-service projections were not made, nor were rate increases and impact assessment fees considered, in this analysis. Furthermore, this study did not assess the impacts of the proposed debt issues on the City's existing debt service coverage. These and other financial issues will be considered following compilation of the comprehensive water master plan. With completion of the planned water distribution system capital outlay plan scheduled for late 2001, a comprehensive financial analysis will be possible.

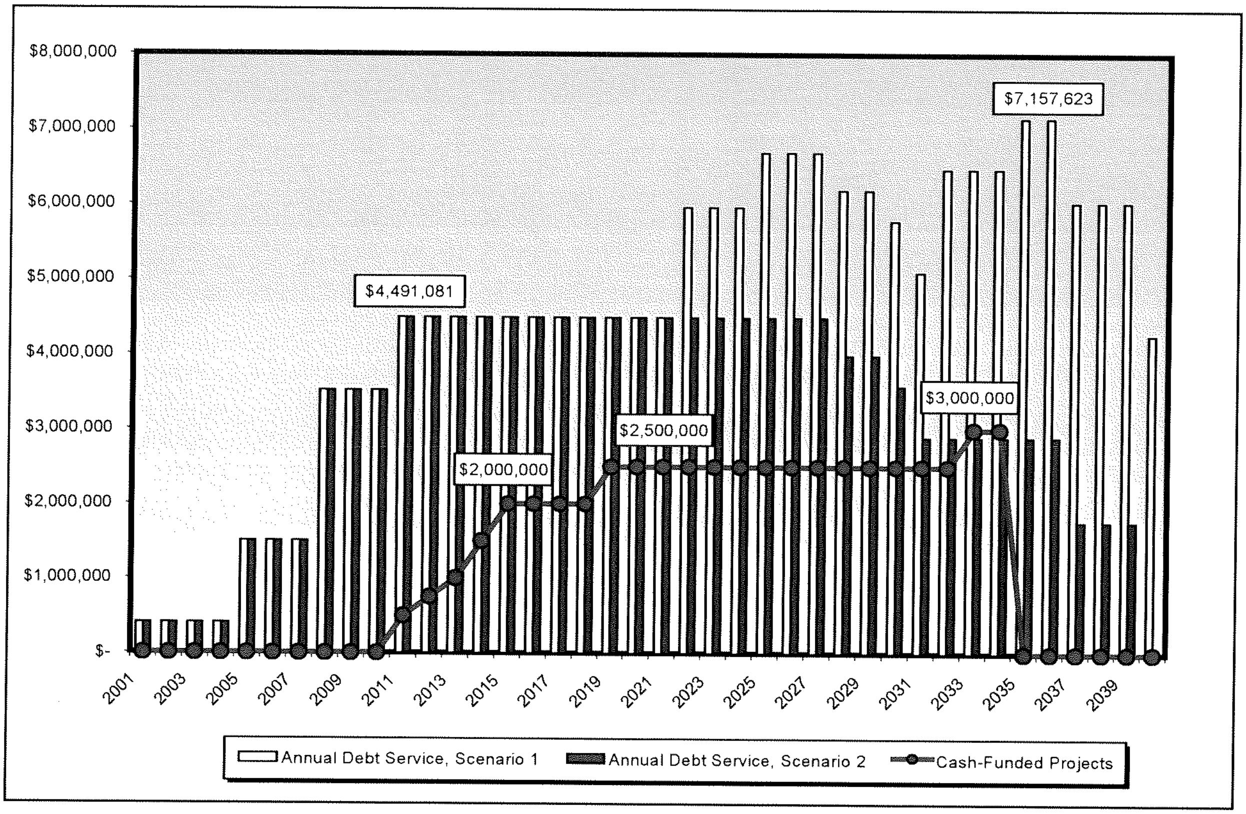


FIGURE 4-1
Norman Strategic Water Supply Plan
Financial Analysis – Projected Annual Debt Service

Appendix A
Population and Peak Day Consumption Analysis Memorandum

DATE: September 17, 1999

TO: Brad Gambill, Director of Utilities
Richard Massie, Director of Planning

FROM: Bryan Mitchell, Capital Projects Engineer

RE: POPULATION AND PEAK DAY CONSUMPTION ANALYSIS

OBJECTIVE:

Determine peak day demand projections through 2040 for use in planning water capacity requirements.

BACKGROUND:

This analysis provides an extension to previous planning documents prepared by engineering and planning consultants for the City of Norman. These documents include: Master Water Plan by CH2M-Hill, October 1992; Land Demand Technical Memorandum, Norman 2020 Land Use and Transportation Plan (Norman 2020) by The Burnham Group, July 7, 1995; The 1990 Population Census Data; The *Estimated Use of Water in the United States in 1995*, The US Geological Survey, 1995; and City staff population projections based on experience.

POPULATION PROJECTIONS:

Population projections presented in the Master Water Plan were compared to population and construction growth data collected by City of Norman staff. Staff determined the population currently connected to the City's water distribution system and assumed that the same percentage (88%) would apply in the future. In addition to this, City staff developed a projected population based on an existing dwelling unit count, an assumed average annual rate of dwelling unit construction, and the assumption of a 95% occupancy rate of the available dwelling units constructed in the future.

The following table summarizes the population data utilized for estimating future water consumption.

Table 1
Water Service Population Projections Considered in this Study

Year	Master Water Plan (High Growth)(1)	Master Water Plan (Low Growth)(1)	Staff's Projection Based from the 1990 Census
2000	88,000	83,600	84,538
2005	92,300	85,600	91,306
2010	96,500	87,700	98,075
2015	100,750	89,700	104,843
2020	105,000	91,700	111,612
2025	109,250	93,750	118,381
2030	113,500	95,800	125,149
2035	117,750	97,850	131,918
2040	122,000	99,900	138,686

(1) Numbers taken directly from the 1992 Master Water Plan

PER CAPITA WATER CONSUMPTION:

The Master Water Plan projected per capita water consumption to continue to increase throughout the study period; however, it also projected the percentage increase could be reduced by 25% if the city implemented water conservation measures such as the *water rationing plan* in effect during the summer of 1998 in Norman. The reduced per capita water usage (with conservation) was considered.

The United States Geological Survey reported in the *Estimated Use of Water in the United States in 1995* that the average per capita water usage in Oklahoma was 194 gallons. Conversely, the City of Norman has historically experienced rates less than this statewide average. Table 2 outlines the observed and projected data used in this review.

PEAK WATER DEMAND:

The Master Water Plan reviewed historic daily water data and determined that the peak daily flow was on average two (2) times the average annual daily demand. It is important to note that the ratio of peak daily demand to average annual daily demand for the years 1980 through 1998 varied from 1.58 to 2.64.

This report assumes the peak daily demand will continue to average two times the average annual daily demand. On occasion, peak daily demand can exceed two times the average daily demand, however, it would likely not be cost effective to construct facilities to handle the projected peak daily demand on an annual basis. In addition of the twice the daily average assumption, a safety factor of 1.05 is included in the calculation of the peak day demand.

Table 2, Table 3, Table 4, and the following graph depicting the projected consumption patterns are based on the four population projections and the two projected per capita usage values.

Table 2
Per Capita Usage Experienced and Projected

Year	Per Capita Usage Projected Rate of Increase	Per Capita Usage Projected with a 25% Rate Decrease
1980	*100*	-
1981	*91*	-
1982	*103*	-
1983	*108*	-
1984	*103*	-
1985	*104*	-
1986	*101*	-
1987	*108*	-
1988	*117*	-
1989	*110*	-
1990	*121*	-
1995	126	119
2000	136	126
2005	146	134
2010	156	141
2015	166	149
2020	176	156
2025	186	164
2030	196	171
2035	206	179
2040	216	186

Note: The italicized values are those reported in the Water Master Plan as experienced values.

Table 3
Projected Average Daily Demand in Million Gallons

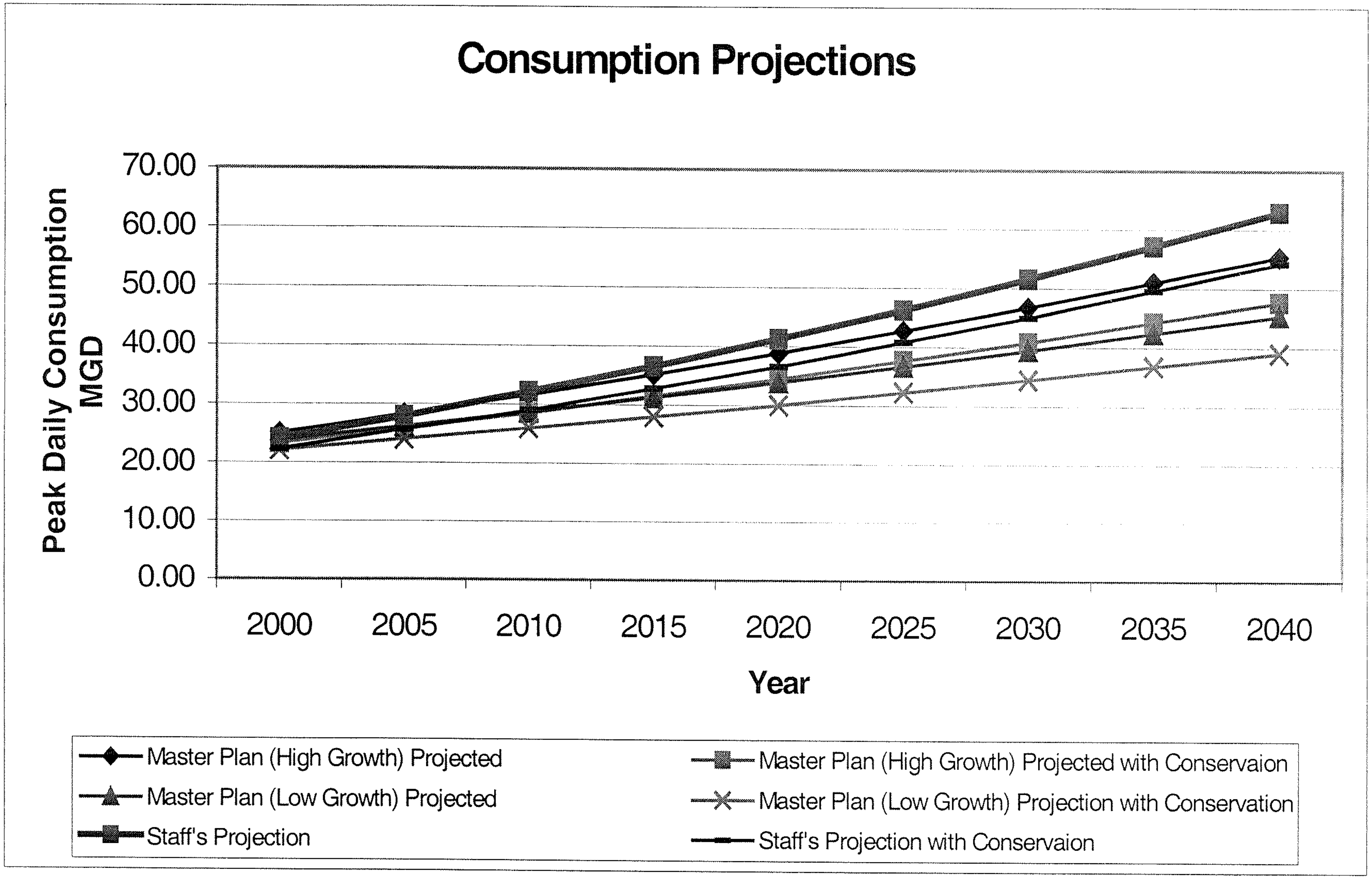
Year	Master Plan (High Growth)		Master Plan (Low Growth)		Staff's Projection	
	Projected	Projected with Conservation	Projected	Projected with Conservation	Projected	Projected with Conservation
2000	11.97	11.09	11.37	10.53	11.50	10.65
2005	13.48	12.37	12.50	11.47	13.33	12.24
2010	15.05	13.61	13.68	12.37	15.30	13.83
2015	16.72	14.96	14.89	13.32	17.40	15.62
2020	18.48	16.38	16.14	14.31	19.64	17.41
2025	20.32	17.86	17.44	15.33	22.02	19.41
2030	22.25	19.41	18.78	16.38	24.53	21.40
2035	24.26	21.02	20.16	17.47	27.18	23.62
2040	26.35	22.69	21.58	18.58	29.96	25.80

Note: Average Daily Demand = Population X Per Capita Consumption

Table 4
Projected Peak Day Demand in Million Gallons

Year	Master Plan (High Growth)		Master Plan (Low Growth)		Staff's Projection	
	Projected	Projected with Conservation	Projected	Projected with Conservation	Projected	Projected with Conservation
2000	25.13	23.28	23.88	22.12	24.14	22.37
2005	28.30	25.97	26.24	24.09	27.99	25.69
2010	31.61	28.57	28.73	25.97	32.13	29.04
2015	35.12	31.42	31.27	27.97	36.55	32.81
2020	38.81	34.40	33.89	30.04	41.25	36.56
2025	42.67	37.51	36.62	32.19	46.24	40.77
2030	46.72	40.76	39.43	34.40	51.51	44.94
2035	50.94	44.14	42.33	36.68	57.07	49.59
2040	55.34	47.65	45.31	39.02	62.91	54.17

Note: Peak Day Demand = Average Day Demand X 2.0 X 1.05


Consumption Projections
Peak Daily Consumption MGD
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
2000
2005
2010
2015
2020
2025
2030
2035
2040
Year
Master Plan (High Growth) Projected
Master Plan (Low Growth) Projected
Staff's Projection
Master Plan (High Growth) Projected with Conservaion
Master Plan (Low Growth) Projection with Conservation
Staff's Projection with Conservaion

Appendix B
Water Quality Data
Water Treatment Plant and Groundwater Wells

Table B-1
Primary Drinking Water Standards

Constituent	US EPA MCLG (mg/L)	US EPA MCL (mg/L)	ODEQ MAL[a] (mg/L)
Fluoride Rule			
Fluoride	4.0	4.0	4.0
Phase I-volatile organics			
Benzene	zero	0.005	0.005
Carbon tetrachloride	zero	0.005	0.005
p-Dichlorobenzene	0.075	0.075	0.075
1,2-Dichloroethane	zero	0.005	0.005
1,1-Dichloroethylene	0.007	0.007	0.007
Trichloroethylene	zero	0.005	0.005
1,1,1-Trichloroethane	0.2	0.2	0.2
Vinyl chloride	zero	0.002	0.002
Total Coliform Rule and Surface Water Treatment Rule			
Giadia lambella	zero	TT[b]	TT[b]
Legionella	zero	TT[b]	TT[b]
Hetertrophic plate count	N/A	TT[b]	TT[b]
Total Coliform	zero	< 5 percent[c]	< 5 percent[c]
Turbidity	N/A	TT[b]	TT[b]
Viruses	zero	TT[b]	TT[b]
Phase II Rule-inorganics			
Asbestos(>10 μm)	7 MFL[d]	7 MFL[d]	7 MFL[d]
Barium	2	2	2
Cadmium	0.005	0.005	0.005
Chromium (total)	0.1	0.1	0.1
Mercury (inorganic)	0.002	0.002	0.002
Nitrate	10	10	10
Nitrite	1	1	1
Nitrate + Nitrite	10	10	10
Selenium	0.05	0.05	0.05

Constituent	US EPA MCLG (mg/L)	US EPA MCL (mg/L)	ODEQ MAL[a] (mg/L)
Phase II Rule-organics			
Acrylamide	zero	TT[b]	TT[b]
Alachlor	zero	0.002	0.002
Atrazine	0.003	0.003	0.003
Carbofuran	0.04	0.04	0.04
Chlordane	zero	0.002	0.002
Chlorobenzene	0.1	0.1	0.1
2,4-D	0.07	0.07	0.07
o-Dichlorobenzene	0.6	0.6	0.6
cis-1,2-Dichlorothylene	0.07	0.07	0.07
trans-1,2-Dichloroehtylene	0.1	0.1	0.1
Dibromochloropropane	zero	0.0002	0.0002
1,2-Dichloropropane	zero	0.005	0.005
Epichlorohydrin	zero	TT[b]	TT[b]
Ethylbenzene	0.7	0.7	0.7
Ethylene dibromide	zero	0.00005	0.00005
Heptachlor	zero	0.0004	0.0004
Heptachlor epoxide	zero	0.0002	0.0002
Lindane	0.0002	0.0002	0.0002
Methoxychlor	0.04	0.04	0.04
Pentachlorophenol	zero	0.001	0.001
PCBs	zero	0.0005	0.0005
Styrene	0.1	0.1	0.1
Tetrachloroethylene	zero	0.005	0.005
Toluene	1	1	1
Toxaphene	zero	0.003	0.003
2,4,5-TP	0.05	0.05	0.05
Xylenes (total)	10	10	10

Constituent	US EPA MCLG (mg/L)	US EPA MCL (mg/L)	ODEQ MAL[a] (mg/L)
Lead and Copper Rule			
Lead	zero	0.015[e]	0.015[e]
Copper	1.3	1.3[e]	1.3[e]
Phase V Rule-inorganics			
Antimony	0.006	0.006	0.006
Beryllium	0.004	0.004	0.004
Cyanide	0.2	0.2	0.2
Nickel	0.1	0.1	0.1
Thallium	0.0005	0.002	0.002
Phase V Rule-organics			
Adipate, [di(2-ethylexyl)]	0.4	0.4	0.4
Dalapon	0.2	0.2	0.2
Dichloromethane	zero	0.005	0.005
Dinoseb	0.007	0.007	0.007
Diquat	0.02	0.02	0.02
Dioxin	zero	$3x10^{-8}$	$3x10^{-8}$
Endothall	0.1	0.1	0.1
Endrin	0.002	0.002	0.002
Glyphosate	0.7	0.7	0.7
Hexachlorobenzene	zero	0.001	0.001
Hexachlorocyclopentadiene	0.05	0.05	0.05
Oxamyl (vydate)	0.2	0.2	0.2
PAHs[benzo(a)pyrene]	zero	0.0002	0.4
Phathalate, [di(2-ethylexyl)]	zero	0.006	0.006
Picloram	0.5	0.5	0.5
Simazine	0.004	0.004	0.004
1,2,4-Trichlorobenzene	0.07	0.07	0.07
1,1,2-Trichloroethane	0.003	0.005	0.005

Constituent	US EPA MCLG (mg/L)	US EPA MCL (mg/L)	ODEQ MAL[a] (mg/L)
Standards for Radionuclides			
Beta and photon emitters	zero[f]	4 mrem/yr	50 pCi/L
Alpha emitters	zero[f]	15 pCi/L	15 pCi/L
Radium 226 + 228	zero[f]	5 pCi/L	5 pCi/L
Other			
Arsenic	-	0.05	0.05
Total Trihalomethane (TTHM)	zero	0.1	0.1

Notes:

a. Maximum Allowable Limit (MAL)
b. Treatment technique requirement
c. For water systems analyzing at least 40 samples per month, no more than 5.0 percent of the monthly samples may be positive for total coliforms.
d. Million Fibers per Liter
e. Action level that triggers treatment.
f. No final MCLG, but zero proposed in 1994.

Table B-2
Treated Water Quality
Inorganic and Microbial Data [a]

Year	Month	Ph[b]	Flouride[b] (mg/L)	Total Alkalinity[b] (mg/L CaCO3)	Total Hardness[b] (mg/L CaCO3)	Turbidity[b] (NTU)	Fe[c] (mg/L)	Mn[c] (mg/L)	Sulfate[c] (mg/L)	Chlorine Residual WTP[b] (mg/L)	Chlorine Residual Distribution[d] (mg/L)	Total Coliform[c] No. of Negative	Total Coliform[c] No. of Positive	Total Coliform[c] Percent Positive
1993	Jun	8.7	1.05	80	110	0.07	0.07	0.01	27.6	2.40	1.08	83	0	0
	Jul	8.7	1.04	77	105	0.07	0.03	-	13.2	2.53	1.03	96	0	0
	Aug	8.8	1.14	83	108	0.06	0.02	0.03	14.2	2.55	1.13	87	0	0
	Sep	8.8	1.13	89	119	0.08	0.01	0.02	13.4	2.52	1.13	86	0	0
	Oct	8.9	1.12	87	120	0.08	0.14	0.02	12.4	2.58	1.31	81	0	0
	Nov	9.0	1.17	97	131	0.17	0.02	0.04	14.2	2.56	1.18	94	0	0
	Dec	8.9	1.30	96	138	0.12	0.02	0.04	-	2.44	1.26	84	0	0
1994	Jan	9.0	1.23	109	153	0.14	0.02	0.03	14.2	2.83	1.27	90	0	0
	Feb	8.9	1.26	105	142	0.11	-	-	-	2.57	1.18	85	0	0
	Mar	8.8	1.16	99	139	0.08	0.05	0.03	12.0	2.45	1.18	91	0	0
	Apr	8.8	1.12	89	126	0.06	0.06	0.02	12.6	2.43	1.12	84	0	0
	May	8.8	1.07	89	140	0.04	0.20	0.04	13.4	2.43	1.06	96	0	0
	Jun	8.7	1.03	89	118	0.05	0.02	0.03	14.2	2.36	0.99	85	0	0
	Jul	8.8	1.00	85	113	0.05	0.01	0.02	14.2	2.32	1.03	86	0	0
	Aug	8.8	1.08	81	90	0.05	0.03	0.30	22.9	2.46	1.05	97	0	0
	Sep	8.8	1.01	80	119	0.05	0.40	0.24	21.8	2.58	1.02	87	0	0
	Oct	9.0	1.00	83	130	0.06	0.24	0.03	13.4	2.64	1.10	85	0	0
	Nov	9.0	1.11	97	141	0.12	0.04	0.03	12.0	2.43	1.08	84	0	0
	Dec	9.0	1.12	85	146	0.10	0.26	0.03	13.0	2.48	1.11	85	0	0
1995	Jan	9.1	1.21	86	149	0.07	0.05	0.04	12.6	2.50	1.13	84	0	0
	Feb	9.1	1.16	90	150	0.09	0.05	0.02	12.6	2.38	1.11	90	0	0
	Mar	9.1	1.24	79	135	0.08	0.03	0.04	12.8	2.47	1.21	89	0	0
	Apr	8.9	1.32	77	126	0.05	0.03	0.03	13.0	2.45	1.22	85	0	0
	May	8.9	1.16	70	121	0.05	0.01	0.03	12.4	2.42	1.24	96	0	0
	Jun	8.8	1.17	55	108	0.06	0.05	0.04	12.6	2.46	1.18	86	0	0
	Jul	8.8	1.05	55	95	0.08	0.05	0.04	12.8	2.54	1.09	94	0	0
	Aug	8.9	1.09	60	113	0.09	0.02	0.20	12.6	2.69	1.09	90	0	0
	Sep	9.0	0.99	58	110	0.08	0.01	0.02	13.4	2.50	1.10	81	0	0
	Oct	9.1	0.99	72	114	0.09	0.02	0.23	14.2	2.86	1.07	99	0	0
	Nov	8.9	1.06	82	122	0.08	0.03	0.04	12.0	2.88	1.08	90	0	0
	Dec	9.1	0.99	80	121	0.13	0.02	0.02	11.8	2.42	1.01	83	0	0
1996	Jan	9.4	1.11	75	119	0.13	0.01	0.02	11.6	2.44	1.07	85	0	0
	Feb	9.4	1.07	82	119	0.09	0.05	1.00	11.2	2.35	1.08	86	0	0
	Mar	8.9	1.10	76	116	0.09	0.05	0.04	12.6	2.52	1.08	94	0	0
	Apr	8.9	1.03	72	113	0.06	0.03	0.03	13.0	2.43	1.06	86	0	0
	May	8.8	1.06	76	108	0.06	0.01	0.03	12.4	2.32	1.10	86	0	0
	Jun	8.8	1.03	73	103	0.04	0.01	0.03	13.0	2.24	1.03	81	0	0
	Jul	8.8	0.98	55	101	0.04	0.01	0.02	12.6	2.40	0.99	97	0	0
	Aug	9.0	1.20	50	101	0.08	0.10	0.02	11.4	2.39	1.16	86	0	0
	Sep	8.9	1.17	53	105	0.04	0.05	0.04	12.1	2.44	1.15	99	0	0
	Oct	9.1	1.07	56	107	0.06	0.02	0.23	14.2	2.50	1.13	80	5	6
	Nov	9.2	1.14	56	111	0.08	-	0.04	12.0	2.45	1.10	108	4	4
	Dec	9.7	1.21	55	107	0.06	0.01	0.04	12.0	2.44	1.12	86	0	0
1997	Jan	9.8	1.22	54	108	0.05	0.04	0.04	12.6	2.40	1.16	99	0	0
	Feb	9.9	1.19	54	106	0.05	0.03	0.03	13.0	2.37	1.12	80	0	0
	Mar	9.7	1.12	51	99	0.04	0.03	0.04	12.8	2.41	1.09	91	0	0
	Apr	9.8	1.15	49	93	0.04	0.05	0.01	12.4	2.42	1.11	86	0	0
	May	9.1	1.05	66	102	0.06	0.01	0.03	12.4	2.52	1.10	96	0	0
	Jun	8.9	0.99	70	109	0.05	0.01	0.02	12.3	2.39	1.14	82	1	1
	Jul	8.9	0.91	69	104	0.05	0.04	0.02	12.6	2.35	1.08	87	2	2
	Aug	9.0	1.01	66	101	0.05	0.05	0.04	12.8	2.40	1.04	101	0	0
	Sep	9.0	1.08	68	101	0.05	0.05	0.04	12.6	2.46	1.05	88	0	0
	Oct	9.0	1.12	74	107	0.05	0.03	0.03	13.0	2.47	1.09	88	0	0
	Nov	9.0	1.12	95	118	0.06	0.01	0.04	11.8	2.54	1.14	86	0	0
	Dec	8.8	1.17	103	132	0.05	0.01	0.04	12.2	2.40	1.07	84	0	0
1998	Jan	8.9	1.19	108	135	0.07	0.01	0.03	11.2	2.54	1.09	86	0	0
	Feb	8.8	1.19	116	124	0.05	0.04	0.03	12.5	2.53	1.21	92	0	0
	Mar	8.8	1.18	103	126	0.06	0.03	0.04	12.8	2.47	1.13	81	0	0
	Apr	8.7	1.04	93	118	0.05	0.03	0.03	12.4	2.34	1.06	85	0	0
	May	8.7	1.07	94	120	0.04	0.01	0.03	13.0	2.63	3.83	101	0	0
	Jun	8.6	1.08	95	119	0.05	0.01	0.03	12.2	2.65	1.11	82	0	0
	Number	61	61	61	61	61	59	59	59	61	61	61	61	61
	Minimum	8.6	0.91	49	90	0.04	0.01	0.01	11.2	2.24	0.99	80	0	0
	Average	9.0	1.11	78	118	0.07	0.05	0.06	13.3	2.48	1.16	89	0	0
	Maximum	9.9	1.32	116	153	0.17	0.40	1.00	27.6	2.88	3.83	108	5	6

Note: [a] Data adopted from City's Operating Report
[b] Monthly averages of daily samples
[c] Monthly samples
[d] Monthly averages of monthly samples

Table B-3

Summary of Well Data [a] [b]

	pH	Total Alkalinity mg/L	Total Hardness mg/L	Calcium Hardness mg/L	Total Dissolved Solids mg/L	Phenols	Arsenic mg/L	Barium mg/L	Chromium mg/L	Iron mg/L	Manganese mg/L	Selenium mg/L	Sulfate mg/L	Chloride mg/L	Flouride mg/L	Nitrate-Nitrite mg/L	Coliforms [b] per 100 mL
EPA Standard	6.5-8.5	[c]	[c]	[c]	500.0	[c]	50.0	2.00	0.10	0.30	0.05	0.05	250.0	250.0	2.00	10.00	5% of Samples
Well 1	8.1	239.9	134.5	51.5													
Well 2	8.1	239.3	89.7	43.8			5.0	0.17	0.08			0.02			0.67	0.21	
Well 3	8.0	246.0	106.6	60.9				0.19	0.07						0.42	0.37	
Well 4	8.5	191.4	95.1	32.2		<0.001	21.0	0.14	0.07	0.12	0.01	0.02	21.8	30.5	0.63	0.45	0
Well 5	7.9	291.2	78.6	28.2			2.0	0.25	0.07						0.70	0.27	
Well 6	8.3	314.2	84.7	32.9	370.0	<0.001	10.0	0.43	0.03	0.06	0.20	0.01	18.4	49.0	0.32	0.20	0
Well 7	8.4	190.7	62.2	32.3		<0.001	28.0	0.06	0.01	0.05	<0.01	0.03	44.2	10.0	0.70	0.18	0
Well 8	8.2	242.0	103.5	48.8	240.0	<0.001	3.0	0.24	0.02	0.05	0.04		24.7	12.5	0.27	0.44	0
Well 11	8.5	185.8	92.3	32.8	240.0	<0.001	35.0	0.13	0.03	0.04	0.02	0.01	18.4	12.0	0.95	0.30	0
Well 12	8.3	327.0	71.8	26.8		<0.001				0.04	0.02		7.3				<1
Well 13	7.8	255.9	134.5	45.8													
Well 14	8.3	258.0	106.7	31.5			27.0	0.13	0.04			0.02			0.90	0.44	
Well 15	8.2	241.2	115.8	65.7			20.0	0.23	0.03						0.26	0.50	
Well 16	8.5	257.6	66.0	38.7	290.0	<0.001	39.0	0.10	0.02	0.07	0.02	0.02	14.2	12.0	0.27	0.53	<1
Well 18	8.5	269.4	48.8	21.9	290.0	<0.001	20.0	0.07		0.06	<0.02	0.01	18.8	12.0	0.20	0.60	<1
Well 19	8.2	206.3	61.9	39.7		<0.001	15.0	0.34	0.01	0.34	0.02		15.2	16.0	0.15	0.64	0
Well 20	8.1	79.3	77.5	51.0		<0.001	4.0	0.98		0.06	<0.01		11.2	8.0	0.73	0.62	2
Well 21	8.2	115.0	72.5	40.8		<0.001	21.0	0.35		0.08	0.01		11.7	18.0	0.84	0.50	0
Well 23	8.2	282.8	47.4	14.9		<0.001	46.0	0.06	0.03	0.08	0.03	0.02	59.5	29.0	0.78	0.30	0
Well 24	8.4	145.0	78.0	30.0		<0.001				0.04	0.01		120.6	40.0	0.58		0
Well 25	8.3	223.4	70.7	35.7		<0.001			0.03	0.15	0.01	<0.01	15.4				<1
Well 31	8.6	238.0	102.1	54.3													
Well 32	8.5	231.4	115.4	60.4						0.29							

Note: [a] Average of samples from Jan 93 - Jun 98. Values reported as <1 indicate test positive samples that could not be replicated.

[b] Data represents total occurence from January 1993 to June 1998

[c] No regulatory limit

Table B-4
TTHM Data [a]

Quarter	Year	Quarterly Average [b] (ug/L)	Running Quarterly Average (ug/L)
Jan-Mar	1993	4.0	-
Mar-Jun	1993	6.8	-
Jul-Sep	1993	7.8	-
Oct-Nov	1993	3.2	5.5
Jan-Mar	1994	5.8	5.9
Mar-Jun	1994	3.2	5.0
Jul-Sep	1994	4.0	4.1
Oct-Nov	1994	12.5	6.4
Jan-Mar	1995	38.0	14.4
Mar-Jun	1995	17.8	18.1
Jul-Sep	1995	8.0	19.1
Oct-Nov	1995	30.0	23.4
Jan-Mar	1996	4.8	15.1
Mar-Jun	1996	11.3	13.5
Jul-Sep	1996	29.0	18.8
Oct-Nov	1996	12.0	14.3
Jan-Mar	1997	10.5	15.7
Mar-Jun	1997	15.0	16.6
Jul-Sep	1997	3.4	10.2
Oct-Nov	1997	9.0	9.5
Jan-Mar	1998	9.0	9.1
Mar-Jun	1998	15.2	9.2
Jul-Sep	1998	2.7	9.0
Oct-Nov	1998	1.3	7.0
Jan-Mar	1999	24.8	11.0
Mar-Jun	1999	20.3	12.2
Jul-Sep	1999	14.3	15.1
	Minimum	1.3	4.1
	Average	12.0	12.0
	Maximum	38.0	23.4

Note: [a] Data adopted from City's Operating Report
[b] Monthly averages of monthly samples

Table B-5
Treated Water Quality
Disinfectant Residuals - Water Treatment Plant & Distribution System [a]

		Chlorine Residual			
		WTP[b]		Distribution[c]	
Year	Month	Monthly Average (mg/L)	Running Annual Average (mg/L)	Monthly Average (mg/L)	Running Annual Average (mg/L)
1993	Jun	2.40	-	1.08	-
	Jul	2.53	2.46	1.03	1.05
	Aug	2.55	2.49	1.13	1.08
	Sep	2.52	2.50	1.13	1.09
	Oct	2.58	2.52	1.31	1.14
	Nov	2.56	2.52	1.18	1.14
	Dec	2.44	2.51	1.26	1.16
1994	Jan	2.83	-	1.27	-
	Feb	2.57	2.70	1.18	1.22
	Mar	2.45	2.62	1.18	1.21
	Apr	2.43	2.57	1.12	1.19
	May	2.43	2.54	1.06	1.16
	Jun	2.36	2.51	0.99	1.13
	Jul	2.32	2.49	1.03	1.12
	Aug	2.46	2.48	1.05	1.11
	Sep	2.58	2.49	1.02	1.10
	Oct	2.64	2.51	1.10	1.10
	Nov	2.43	2.50	1.08	1.10
	Dec	2.48	2.50	1.11	1.10
1995	Jan	2.50	-	1.13	-
	Feb	2.38	2.44	1.11	1.12
	Mar	2.47	2.45	1.21	1.15
	Apr	2.45	2.45	1.22	1.17
	May	2.42	2.44	1.24	1.18
	Jun	2.46	2.45	1.18	1.18
	Jul	2.54	2.46	1.09	1.17
	Aug	2.69	2.49	1.09	1.16
	Sep	2.50	2.49	1.10	1.15
	Oct	2.86	2.53	1.07	1.14
	Nov	2.88	2.56	1.08	1.14
	Dec	2.42	2.55	1.01	1.13
1996	Jan	2.44	-	1.07	-
	Feb	2.35	2.39	1.08	1.07
	Mar	2.52	2.43	1.08	1.08
	Apr	2.43	2.43	1.06	1.07
	May	2.32	2.41	1.10	1.08
	Jun	2.24	2.38	1.03	1.07
	Jul	2.40	2.38	0.99	1.06
	Aug	2.39	2.38	1.16	1.07
	Sep	2.44	2.39	1.15	1.08
	Oct	2.50	2.40	1.13	1.08
	Nov	2.45	2.41	1.10	1.08
	Dec	2.44	2.41	1.12	1.09
1997	Jan	2.40	-	1.16	-
	Feb	2.37	2.39	1.12	1.14
	Mar	2.41	2.39	1.09	1.13
	Apr	2.42	2.40	1.11	1.12
	May	2.52	2.43	1.10	1.12
	Jun	2.39	2.42	1.14	1.12
	Jul	2.35	2.41	1.08	1.12
	Aug	2.40	2.41	1.04	1.11
	Sep	2.46	2.41	1.05	1.10
	Oct	2.47	2.42	1.09	1.10
	Nov	2.54	2.43	1.14	1.10
	Dec	2.40	2.43	1.07	1.10
1998	Jan	2.54	-	1.09	-
	Feb	2.53	2.54	1.21	1.15
	Mar	2.47	2.51	1.13	1.15
	Apr	2.34	2.47	1.06	1.12
	May	2.63	2.50	3.83	1.66
	Jun	2.65	2.53	1.11	1.57
	Number	61	55	61	55
	Minimum	2.24	2.38	0.99	1.05
	Average	2.48	2.47	1.16	1.14
	Maximum	2.88	2.70	3.83	1.66

Note: [a] Data adopted from City's Operating Report
[b] Monthly averages of daily samples
[c] Monthly averages of monthly samples

Table B-6
Treated Water Quality
Total Alkalinity and Magnesium Hardness WTP Data [a]

		Total Alkalinity[b]		Magnesium Hardness[b]	
		Raw Water	Finished Water	Raw Water	Finished Water
Year	Month	(mg/L $CaCO_3$)	(mg/L $CaCO_3$)	(mg/L)	(mg/L)
1993	Jun	166.5	80.2	29.0	61.0
	Jul	172.5	77.2	31.5	57.5
	Aug	170.5	82.9	35.0	58.0
	Sep	160.0	89.2	35.5	68.0
	Oct	161.0	87.1	73.0	73.0
	Nov	169.0	96.9	47.5	78.0
	Dec	173.5	95.7	43.5	86.5
1994	Jan	175.5	108.6	45.0	85.5
	Feb	178.5	105.4	37.5	97.5
	Mar	176.0	98.6	35.0	89.0
	Apr	174.5	89.3	30.0	77.5
	May	178.0	88.8	29.0	70.5
	Jun	177.0	89.3	32.0	65.5
	Jul	175.5	85.4	29.5	61.5
	Aug	164.5	80.8	31.5	55.0
	Sep	162.5	79.5	35.5	67.5
	Oct	161.5	83.0	37.5	73.5
	Nov	152.5	96.9	37.5	73.0
	Dec	141.0	85.0	39.0	78.5
1995	Jan	139.0	86.0	45.5	82.0
	Feb	143.5	89.8	38.5	85.5
	Mar	141.5	79.0	32.5	77.5
	Apr	144.5	77.1	29.0	75.0
	May	145.0	69.7	32.5	74.5
	Jun	125.0	55.2	28.0	65.5
	Jul	128.0	55.2	30.0	53.5
	Aug	136.5	59.7	45.5	66.5
	Sep	130.5	58.4	30.0	62.5
	Oct	137.5	71.7	31.0	59.0
	Nov	145.0	81.6	29.5	68.0
	Dec	153.5	79.8	25.5	69.5
1996	Jan	154.5	75.5	29.5	62.0
	Feb	158.5	81.7	24.0	64.0
	Mar	161.5	75.7	27.5	68.5
	Apr	162.5	72.0	22.5	61.0
	May	167.0	76.0	24.0	57.5
	Jun	162.5	73.1	20.5	57.5
	Jul	133.0	55.0	27.5	58.0
	Aug	116.0	49.9	33.5	54.0
	Sep	112.5	53.1	28.0	63.0
	Oct	114.0	55.7	28.0	62.5
	Nov	117.0	55.6	28.5	60.0
	Dec	116.5	54.8	25.5	52.0
1997	Jan	121.0	54.3	30.0	47.0
	Feb	128.5	54.2	39.5	51.5
	Mar	141.5	51.0	40.5	47.0
	Apr	160.5	48.9	40.5	45.5
	May	145.5	66.1	49.5	57.0
	Jun	165.0	70.0	51.5	63.5
	Jul	146.0	68.8	58.5	58.5
	Aug	166.5	66.2	52.0	56.0
	Sep	168.0	67.6	61.5	60.5
	Oct	168.0	73.8	61.5	62.5
	Nov	166.0	95.1	56.0	70.5
	Dec	161.0	103.5	56.0	84.5
1998	Jan	161.0	107.8	54.5	83.0
	Feb	164.5	115.9	53.5	76.5
	Mar	163.0	102.7	48.5	76.0
	Apr	165.5	93.4	50.0	70.0
	May	160.0	94.4	53.5	71.0
	Jun	158.0	94.6	54.0	69.0
	Number	61.0	61.0	61.0	61.0
	Minimum	112.5	48.9	20.5	45.5
	Average	153.2	78.2	38.4	67.0
	Maximum	178.5	115.9	73.0	97.5

Note: [a] Data adopted from City's Operating Report
[b] Monthly averages of daily samples

Table B-7
Raw Water and Finished Water Quality [a]
Turbidity

Year	Month	Turbidity: Raw Water (NTU) [b]	Turbidity: Tap Water (NTU) [b]
1993	Jun	18.0	0.00
	Jul	14.0	0.03
	Aug	13.0	0.07
	Sep	15.0	0.09
	Oct	15.0	0.09
	Nov	14.0	0.18
	Dec	15.0	0.13
1994	Jan	11.0	0.15
	Feb	7.0	0.12
	Mar	16.0	0.09
	Apr	17.0	0.07
	May	11.0	0.05
	Jun	13.0	0.06
	Jul	8.0	0.05
	Aug	9.0	0.06
	Sep	13.0	0.06
	Oct	13.0	0.07
	Nov	12.0	0.13
	Dec	10.0	0.11
1995	Jan	8.0	0.07
	Feb	8.0	0.10
	Mar	12.0	0.08
	Apr	15.0	0.05
	May	18.0	0.05
	Jun	18.0	0.08
	Jul	13.0	0.09
	Aug	10.0	0.09
	Sep	7.0	0.08
	Oct	15.0	0.10
	Nov	14.0	0.09
	Dec	14.0	0.13
1996	Jan	11.0	0.13
	Feb	8.0	0.09
	Mar	13.0	0.09
	Apr	14.0	0.06
	May	15.0	0.05
	Jun	14.0	0.04
	Jul	7.0	0.04
	Aug	6.0	0.08
	Sep	7.0	0.05
	Oct	11.0	0.07
	Nov	13.0	0.09
	Dec	17.0	0.07
1997	Jan	12.0	0.06
	Feb	13.0	0.05
	Mar	20.0	0.05
	Apr	19.0	0.04
	May	13.0	0.07
	Jun	8.0	0.06
	Jul	7.0	0.06
	Aug	5.0	0.07
	Sep	7.0	0.06
	Oct	7.0	0.06
	Nov	8.0	0.07
	Dec	7.0	0.05
1998	Jan	21.0	0.07
	Feb	20.0	0.06
	Mar	21.0	0.06
	Apr	22.0	0.05
	May	12.0	0.04
	Jun	7.0	0.06
Number		61.0	61.0
Minimum		5.0	0.00
Average		12.5	0.07
Maximum		22.0	0.18

Note: [a] Data adopted from City's Operating Report
[b] Monthly averages of daily samples

Table B-8
Treated Water Quality
Sulfate Data [a]

Year	Month	Sulfate[b](mg/L)
1993	Jun	27.6
	Jul	13.2
	Aug	14.2
	Sep	13.4
	Oct	12.4
	Nov	14.2
	Dec	-
1994	Jan	14.2
	Feb	-
	Mar	12.0
	Apr	12.6
	May	13.4
	Jun	14.2
	Jul	14.2
	Aug	22.9
	Sep	21.8
	Oct	13.4
	Nov	12.0
	Dec	13.0
1995	Jan	12.6
	Feb	12.6
	Mar	12.8
	Apr	13.0
	May	12.4
	Jun	12.6
	Jul	12.8
	Aug	12.6
	Sep	13.4
	Oct	14.2
	Nov	12.0
	Dec	11.8
1996	Jan	11.6
	Feb	11.2
	Mar	12.6
	Apr	13.0
	May	12.4
	Jun	13.0
	Jul	12.6
	Aug	11.4
	Sep	12.1
	Oct	14.2
	Nov	12.0
	Dec	12.0
1997	Jan	12.6
	Feb	13.0
	Mar	12.8
	Apr	12.4
	May	12.4
	Jun	12.3
	Jul	12.6
	Aug	12.8
	Sep	12.6
	Oct	13.0
	Nov	11.8
	Dec	12.2
1998	Jan	11.2
	Feb	12.5
	Mar	12.8
	Apr	12.4
	May	13.0
	Jun	12.2
	Number	59
	Minimum	11.2
	Average	13.3
	Maximum	27.6

Note: [a] Data adopted from City's Operating Report
[b] Monthly samples

Table B-9
Groundwater Wells
Sulfate and Arsenic Data [a]

Well Number	Sulfate (mg/L)	Arsenic (ug/L)
Well 1	-	-
Well 2	-	-
Well 3	-	-
Well 4	21.8	21
Well 5	-	2
Well 6	18.4	10
Well 7	44.2	28
Well 8	24.7	3
Well 11	18.4	35
Well 12	7.3	-
Well 13	-	-
Well 14	-	27
Well 15	-	20
Well 16	14.2	39
Well 18	18.8	20
Well 19	15.2	15
Well 20	11.2	4
Well 21	11.7	21
Well 23	59.5	46
Well 24	120.6	-
Well 25	15.4	-
Well 31	-	-
Well 32	-	-

Note: [a] Data adopted from Groundwater Well Operating Logs

Appendix C
South Canadian River Water System
Estimates of Capital and O&M Cost Opinions

Table C-1
South Canadian River
Opinions of Cost

		Quantity	Unit	Unit Cost	Cost	Subtotal	Total
I	**South Canadian River**						
	Water Permit	50	mgd	$ 260	$ 13,000		
	Intake Structure	50	mgd	$ 58,000	$ 2,900,000		
	Pump Station	50	mgd	$ 33,000	$ 1,650,000		
	Site Piping	50	mgd	$ 39,000	$ 1,950,000		
	Site Work	50	mgd	$ 21,000	$ 1,050,000		
	Site Electrical / I&C	-	LS	$ 910,000	$ 910,000		
	Subtotal	-	-			$ 8,470,000	
	Contigency (20%)	-	LS		$ 1,690,000	$ 1,690,000	
							$ 10,160,000
II	**Raw Water Conveyance Piping**						
	48-inch Piping	13,000	lf	$ 192	$ 2,500,000		
	Easments / Right-of-Ways	-	LS	$ 500,000	$ 500,000		
	Outlet Structure	-	LS	$ 150,000	$ 150,000		
	Subtotal					$ 3,150,000	
	Contigency (20%)	-	LS		$ 630,000	$630,000	
							$ 3,780,000
III	**West Side Reservoir**						
	Land Acquisition	600	acre	$ 4,000	$ 2,400,000		
	Reservoir Construction	8,400	acre-ft	$ 1,200	$ 10,080,000		
	Inlet Structure	-	LS	$ 210,000	$ 210,000		
	Pump Station	22	mgd	$ 33,000	$ 726,000		
	Site Piping	22	mgd	$ 39,000	$ 858,000		
	Site Electrical / I&C	-	LS	$ 220,000	$ 220,000		
	Utility Relocation	-	LS	$ 750,000	$ 750,000		
	Subtotal					$ 15,240,000	
	Contigency (35%)	-	LS		$ 5,330,000	$5,330,000	
							$ 20,570,000
IV	**South Canadian WTP**						
	Land Acquisition	40	acre	$ 4,000	$ 160,000		
	Pretreatment	22	mgd	$ 140,000	$ 3,080,000		
	Chemical Feed Facility	22	mgd	$ 160,000	$ 3,520,000		
	Membrane Treatment Facility	22	mgd	$ 680,000	$ 14,960,000		
	Sludge/Reject	22	mgd	$ 60,000	$ 1,320,000		
	Admin/Mant. Building	-	LS	$ 2,000,000	$ 2,000,000		
	Clearwell	22	mgd	$ 90,000	$ 1,980,000		
	HSPS (1.8 x WTP Capacity)	40	mgd	$ 38,000	$ 1,520,000		
	Yard Piping	22	mgd	$ 80,000	$ 1,760,000		
	Site Work	22	mgd	$ 60,000	$ 1,320,000		
	Site Electrical / I&C	-	LS	$ 3,780,000	$ 3,780,000		
	Subtotal					$ 35,400,000	
	Contigency (20%)	-	LS		$ 7,080,000	$7,080,000	
							$ 42,480,000
V	**Total Opinion of Cost**						**$ 76,990,000**

Note:
Conveyance cost estimates do not include right-of-way costs.

Table C-2
South Canadian River
Opinions of Cost

	Quantity	Unit	Unit Cost	Cost	Subtotal	Total
I South Canadian River						
Water Permit	50	mgd	$ 260	$ 13,000		
Intake Structure	50	mgd	$ 58,000	$ 2,900,000		
Pump Station	50	mgd	$ 33,000	$ 1,650,000		
Site Piping	50	mgd	$ 39,000	$ 1,950,000		
Site Work	50	mgd	$ 21,000	$ 1,050,000		
Site Electrical / I&C	-	LS	$ 910,000	$ 910,000		
Subtotal	-	-			$ 8,470,000	
Contigency (20%)	-	LS		$ 1,690,000		
						$ 10,160,000
II Raw Water Conveyance Piping: West Side Reservoir						
48-inch Piping	13,000	lf	$ 192	$ 2,496,000		
Easments / Right-of-Ways	-	LS	$ 500,000	$ 500,000		
Outlet Structure	-	LS	$ 150,000	$ 150,000		
Subtotal					$ 3,150,000	
Contigency (20%)	-	LS		$ 630,000		
						$ 3,780,000
III West Side Reservoir						
Land Acquisition	320	acre	$ 4,000	$ 1,280,000		
Reservoir Construction	4,400	acre-ft	$ 1,200	$ 5,280,000		
Inlet Structure	-	LS	$ 190,000	$ 190,000		
Pump Station	10	mgd	$ 33,000	$ 330,000		
Site Piping	10	mgd	$ 39,000	$ 390,000		
Site Electrical / I&C	-	LS	$ 110,000	$ 110,000		
Utility Relocation	-	LS	$ 390,000	$ 390,000		
Subtotal					$ 7,970,000	
Contigency (35%)	-	LS		$ 2,790,000		
						$ 10,760,000
IV Raw Water Conveyance Piping: East Side (Campbell) Reservoir						
24-inch Piping	69,000	lf	$ 96	$ 6,624,000		
Easments / Right-of-Ways	-	LS	$ 1,320,000	$ 1,320,000		
Outlet Structure	-	LS	$ 95,000	$ 95,000		
Subtotal					$ 8,040,000	
Contigency (20%)	-	LS		$ 1,610,000		
						$ 9,650,000
V East Side (Campbell) Reservoir						
Land Acquisition	660	acre	$ 4,000	$ 2,640,000		
Reservoir Construction	5,000	acre-ft	$ 1,200	$ 6,000,000		
Inlet Structure	-	LS	$ 210,000	$ 210,000		
Pump Station	22	mgd	$ 33,000	$ 726,000		
Site Piping	22	mgd	$ 39,000	$ 858,000		
Site Electrical / I&C	-	LS	$ 220,000	$ 220,000		
Utility Relocation	-	LS	$ 520,000	$ 520,000		
Subtotal					$ 11,170,000	
Contigency (35%)	-	LS		$ 3,910,000		
						$ 15,080,000
VI Norman WTP: South Canadian Treatment Train						
Pretreatment	22	mgd	$ 140,000	$ 3,080,000		
Chemical Feed Facility Expansion	22	mgd	$ 105,000	$ 2,310,000		
Membrane Treatment Facility	22	mgd	$ 680,000	$ 14,960,000		
Sludge/Reject	22	mgd	$ 54,000	$ 1,188,000		
Admin/Mant. Building Upgrade	-	LS	$ 510,000	$ 510,000		
Clearwell	22	mgd	$ 90,000	$ 1,980,000		
HSPS (1.8 x WTP Capacity)	40	mgd	$ 38,000	$ 1,520,000		
Yard Piping	22	mgd	$ 72,000	$ 1,584,000		
Site Work	22	mgd	$ 42,000	$ 924,000		
Site Electrical / I&C	-	LS	$ 3,370,000	$ 3,370,000		
Subtotal					$ 31,430,000	
Contigency (20%)	-	LS		$ 6,290,000		
						$ 37,720,000
VII Total Opinion of Cost						**$ 87,150,000**

Note:
Conveyance cost estimates do not include right-of-way costs.

Table C-3
Norman Strategic Water Supply Plan
Water Supply Plan Alternative A

Item		Description	Cost	Total
Capital				
I OKC Treated Water Transmission Line		32-inch diameter	$ 2,028,000	
II Lake Campbell		3,200 acre-ft	$ 11,664,000	
III WTP Conveyance Pipeline Replacement		30-inch diameter	$ 6,211,000	
				$ 19,903,000
Annual O&M				
I Existing Wellfield (with expansion)		31 wells	$ 307,000	
II Existing WTP		8.4 MGD annual average	$ 1,604,000	
III WTP Reservoir O&M and Conveyance				
	2005-2040	8.4 MGD annual average	$ 318,000	
IV OKC Treated Water Purchase				
	2000	7.0 MGD	$ 4,215,750	
	2005	9.4 MGD	$ 5,661,150	
	2010	11.9 MGD	$ 7,166,775	
	2015	14.6 MGD	$ 8,792,850	
	2020	17.4 MGD	$ 10,479,150	
	2025	20.3 MGD	$ 12,225,675	
	2030	23.3 MGD	$ 14,032,425	
	2035	26.5 MGD	$ 15,959,625	
	2040	29.3 MGD	$ 17,645,925	
V Annual O&M Summary				
	2000	annual total		$ 6,126,750
	2005	annual total		$ 7,890,150
	2010	annual total		$ 9,395,775
	2015	annual total		$ 11,021,850
	2020	annual total		$ 12,708,150
	2025	annual total		$ 14,454,675
	2030	annual total		$ 16,261,425
	2035	annual total		$ 18,188,625
	2040	annual total		$ 19,874,925
40-Year Present Worth Summary				
I *Capital*				
Conveyance and Transmission			$ 19,903,000	
Total				$ 19,903,000
II *O&M*				
Existing Wellfield (with expansion)			$ 8,398,000	
Treatment / Production			$ 50,785,000	
OKC Treated Water Purchase			$ 275,553,000	
Total				$ 334,736,000

Notes:
Present Worth assumes n = 40 yr, annual increase in O&M cost of 3% and interest rate of 5% for an effective i = 2%
Conveyance cost estimates do not include right-of-way costs.

Table C-4
Norman Strategic Water Supply Plan
Water Supply Plan Alternative B

Item		Description	Cost	Total
Capital				
I New Wellfield		30 new wells	$ 5,748,000	
II Wellhead Land Purchase		30 acres	$ 150,000	
III New Wellfield Disinfection System		14 MGD capacity	$ 2,078,000	
IV Wellfield Transmission Network		8- to 24-inch diameter	$ 7,350,000	
V Lake Campbell		3,200 acre-ft	$ 11,664,000	
VI WTP Conveyance Pipeline Replacement		30-inch diameter	$ 6,211,000	
VII OKC Treated Water Transmission Line		21-inch diameter	$ 1,331,000	
				$ 34,532,000
Annual O&M				
I Existing WTP		8.4 MGD annual average	$ 1,604,000	
II WTP Reservoir O&M and Conveyance				
	2005-2040	8.4 MGD annual average	$ 318,000	
II Wellfield (Existing with expansion and New)				
	2000	31 wells	$ 307,000	
	2005	46 wells	$ 746,000	
	2010 - 2040	61 wells	$ 1,184,000	
II New Wellfield Disinfection System				
	2005	5 MGD capacity	$ 22,500	
	2010-2040	14 MGD capacity	$ 45,000	
III OKC Treated Water Purchase				
	2000	7.0 MGD	$ 4,215,750	
	2005	4.4 MGD	$ 2,649,900	
	2010	2.0 MGD	$ 1,144,275	
	2015	4.6 MGD	$ 2,770,350	
	2020	7.4 MGD	$ 4,456,650	
	2025	10.3 MGD	$ 6,203,175	
	2030	13.3 MGD	$ 8,009,925	
	2035	16.5 MGD	$ 9,937,125	
	2040	19.3 MGD	$ 11,623,425	
IV Annual O&M Summary				
	2000	annual total		$ 6,126,750
	2005	annual total		$ 5,340,400
	2010	annual total		$ 4,295,275
	2015	annual total		$ 5,921,350
	2020	annual total		$ 7,607,650
	2025	annual total		$ 9,354,175
	2030	annual total		$ 11,160,925
	2035	annual total		$ 13,088,125
	2040	annual total		$ 14,774,425
40-Year Present Worth Summary				
I *Capital*				
Wellfield			$ 5,898,000	
Conveyance / Transmission			$ 26,556,000	
Treatment / Production			$ 2,078,000	
Total				$ 34,532,000
II *O&M*				
Wellfield			$ 29,022,000	
OKC Treated Water Purchase			$ 136,032,000	
Treatment / Production			$ 53,432,000	
Total				$ 218,486,000

Notes:

Present Worth assumes n = 40 yr, annual increase in O&M cost of 3% and interest rate of 5% for an effective i = 2%
Conveyance cost estimates do not include right-of-way costs.

Table C-5
Norman Strategic Water Supply Plan
Water Supply Plan Alternative C

Item	Description	Cost	Total
Capital			
I New Wellfield	30 new wells	$ 5,748,000	
II Wellhead Land Purchase	30 acres	$ 150,000	
III New Wellfield Disinfection System	14 MGD capacity	$ 2,078,000	
IV Wellfield Transmission Network	8- to 24-inch diameter	$ 7,350,000	
V WTP Conveyance Pipeline Expansion	44 MGD WTP capacity	$ 9,906,000	
VI Lake Campbell	3,200 acre-ft	$ 11,664,000	
VII WTP Expansion	44 MGD WTP capacity	$ 43,337,000	
VIII Atoka Pipeline Diversion and Meter Box	20 MGD capacity	$ 250,000	
			$ 80,483,000
Annual O&M			
I WTP			
2000	8.4 MGD annual average	$ 1,604,000	
2005	12.8 MGD annual average	$ 2,446,000	
2010	10.3 MGD annual average	$ 1,968,000	
2015	13 MGD annual average	$ 2,485,000	
2020	15.8 MGD annual average	$ 3,019,000	
2025	18.7 MGD annual average	$ 3,574,000	
2030	21.7 MGD annual average	$ 4,147,000	
2035	24.9 MGD annual average	$ 4,759,000	
2040	27.7 MGD annual average	$ 5,294,000	
II WTP Reservoir O&M and Conveyance			
2005-2020	annual average	$ 335,000	
2025-2035	annual average	$ 352,000	
2035-3040	annual average	$ 475,000	
II Wellfield (Existing with expansion and New)			
2000	31 wells	$ 307,000	
2005	46 wells	$ 746,000	
2010 - 2040	61 wells	$ 1,184,000	
II New Wellfield Disinfection System			
2005	5 MGD annual average	$ 22,500	
2010-2040	10 MGD annual average	$ 45,000	
III OKC Treated Water Purchase			
2000	7.0 MGD	$ 4,215,750	
IV OKC Raw Water Purchase			
2005	4.4 MGD	$ 1,332,980	
2010	1.9 MGD	$ 575,605	
2015	4.6 MGD	$ 1,393,570	
2020	7.4 MGD	$ 2,241,830	
2025	10.3 MGD	$ 3,120,385	
2030	13.3 MGD	$ 4,029,235	
2035	16.5 MGD	$ 4,998,675	
2040	19.3 MGD	$ 5,846,935	
V Annual O&M Summary			
2000	annual total		$ 6,126,750
2005	annual total		$ 4,882,480
2010	annual total		$ 4,107,605
2015	annual total		$ 5,442,570
2020	annual total		$ 6,824,830
2025	annual total		$ 8,275,385
2030	annual total		$ 9,757,235
2035	annual total		$ 11,461,675
2040	annual total		$ 12,844,935

40-Year Present Worth Summary

Item	Cost	Total
I *Capital*		
Wellfield	$ 5,898,000	
Conveyance / Transmission	$ 29,170,000	
Treatment / Production	$ 45,415,000	
Total		$ 80,483,000
II *O&M*		
Wellfield	$ 29,022,000	
OKC Treated Water Purchase	$ 17,317,000	
OKC Raw Water Purchase	$ 59,717,000	
Treatment / Production	$ 89,628,000	
Total		$ 195,684,000

Notes:

Present Worth assumes n = 40 yr, annual increase in O&M cost of 3% and interest rate of 5% for an effective i = 2%

Conveyance cost estimates do not include right-of-way costs.

Table C-6
Norman Strategic Water Supply Plan
Water Supply Plan Alternative D

Item		Description	Cost	Total
Capital				
I New Wellfield		30 new wells	$ 5,748,000	
II Wellhead Land Purchase		30 acres	$ 150,000	
III New Wellfield Disinfection System		14 MGD capacity	$ 2,078,000	
IV Wellfield Transmission Network		8- to 24-inch diameter	$ 7,350,000	
V WTP Conveyance Pipeline Expansion		44 MGD WTP capacity	$ 9,906,000	
VI Lake Campbell		3,200 acre-ft	$ 11,664,000	
VII WTP Expansion		44 MGD WTP capacity	$ 43,337,000	
VIII Atoka Pipeline Diversion and Meter Box		20 MGD capacity	$ 250,000	
IX Hugo Reservoir		30 MGD supply	$ 3,583,000	
X Hugo Reservoir Conveyance System		30 MGD supply	$ 89,678,000	
				$ 173,744,000
Annual O&M				
I WTP				
	2000	8.4 MGD annual average	$ 1,604,000	
	2005	12.8 MGD annual average	$ 2,446,000	
	2010	10.3 MGD annual average	$ 1,968,000	
	2015	13 MGD annual average	$ 2,485,000	
	2020	15.8 MGD annual average	$ 3,019,000	
	2025	18.7 MGD annual average	$ 3,574,000	
	2030	21.7 MGD annual average	$ 4,147,000	
	2035	24.9 MGD annual average	$ 4,759,000	
	2040	27.7 MGD annual average	$ 5,294,000	
II WTP Reservoir O&M and Conveyance				
	2005-2020	annual average	$ 335,000	
	2025-2035	annual average	$ 352,000	
	2035-3040	annual average	$ 475,000	
III Hugo Conveyance System				
	2020	7.4 MGD annual average	$ 444,000	
	2025	10.3 MGD annual average	$ 618,000	
	2030	13.3 MGD annual average	$ 798,000	
	2035	16.5 MGD annual average	$ 990,000	
	2040	19.3 MGD annual average	$ 1,158,000	
IV Hugo Reservoir				
	2020-2040	reservoir O&M	$ 72,210	
V Wellfield (Existing with expansion and New)				
	2000	31 wells	$ 307,000	
	2005	46 wells	$ 746,000	
	2010 - 2040	61 wells	$ 1,184,000	
VI New Wellfield Disinfection System				
	2005	5 MGD annual average	$ 22,500	
	2010-2040	10 MGD annual average	$ 45,000	
VII OKC Treated Water Purchase				
	2000	7.0 MGD	$ 4,215,750	
VIII OKC Raw Water Purchase				
	2005	4.4 MGD	$ 1,332,980	
	2010	1.9 MGD	$ 575,605	
	2015	4.6 MGD	$ 1,393,570	
IX Annual O&M Summary				
	2000	annual total		$ 6,126,750
	2005	annual total		$ 4,882,480
	2010	annual total		$ 4,107,605
	2015	annual total		$ 5,442,570
	2020	annual total		$ 5,099,210
	2025	annual total		$ 5,845,210
	2030	annual total		$ 6,598,210
	2035	annual total		$ 7,525,210
	2040	annual total		$ 8,228,210
40-Year Present Worth Summary				
I *Capital*				
Wellfield			$ 5,898,000	
Hugo Reservoir			$ 3,583,000	
Conveyance / Transmission			$ 118,848,000	
Treatment / Production			$ 45,415,000	
Total				$ 173,744,000
II *O&M*				
Wellfield			$ 29,022,000	
OKC Treated Water Purchase			$ 17,317,000	
OKC Raw Water Purchase			$ 14,213,000	
Hugo Reservoir O&M			$ 843,000	
Hugo Raw Water Conveyance			$ 9,012,000	
Treatment / Production			$ 89,628,000	
Total				$ 160,035,000

Notes:
Present Worth assumes n = 40 yr, annual increase in O&M cost of 3% and interest rate of 5% for an effective i = 2%
Conveyance cost estimates do not include right-of-way costs.

Table C-7
Norman Strategic Water Supply Plan
Water Supply Plan Alternative E

Item		Description	Cost	Total
Capital				
I New Wellfield		30 new wells	$ 5,748,000	
II Wellhead Land Purchase		30 acres	$ 150,000	
III New Wellfield Disinfection System		14 MGD capacity	$ 2,078,000	
IV Wellfield Transmission Network		8- to 24-inch diameter	$ 7,350,000	
V WTP Conveyance Pipeline Replacement		30-inch diameter	$ 6,211,000	
VI South Canadian River		50 MGD Intake capacity	$ 10,160,000	
VII S. C. Conveyance Piping (West Side Reservoir)		50 MGD conveyance capacity	$ 3,780,000	
VIII West Side Reservoir		4,400 acre-ft	$ 10,760,000	
IX S. C. Conveyance Piping (East Side Reservoir)		10 MGD conveyance capacity	$ 9,650,000	
X East Side Reservoir		5,000 acre-ft	$ 15,080,000	
XI Norman WTP: South Canadian Treatment Train		22 MGD treatment capacity	$ 37,720,000	
				$ 108,687,000
Annual O&M				
I WTP (Existing and S.C. Train)				
	2000 - 2005	8.4 MGD annual average	$1,604,000	
	2010	10.3 MGD annual average	$2,117,000	
	2015	13 MGD annual average	$2,846,000	
	2020	15.8 MGD annual average	$3,602,000	
	2025-2040	18.4 MGD annual average	$4,304,000	
II South Canadian Conveyance System				
	2010	annual average	$85,500	
	2015	annual average	$207,000	
	2020	annual average	$333,000	
	2025-2040	annual average	$450,000	
III South Canadian Reservoirs				
	2010-2040	reservoir O&M	$260,000	
IV Wellfield (Existing with expansion and new)				
	2000	31 wells	$307,000	
	2005	46 wells	$746,000	
	2010 - 2040	61 wells	$1,184,000	
V New Wellfield Disinfection System				
	2005	5 MGD annual average	$22,500	
	2010-2040	10 MGD annual average	$45,000	
VI OKC Treated Water Purchase				
	2000	7.0 MGD	$4,215,750	
	2005	5.0 MGD	$3,011,250	
	2025	0.3 MGD	$180,675	
	2030	3.3 MGD	$1,987,425	
	2035	6.5 MGD	$3,914,625	
	2040	9.3 MGD	$5,600,925	
VIII Annual O&M Summary				
	2000	annual total		$6,126,750
	2005	annual total		$5,383,750
	2010	annual total		$3,691,500
	2015	annual total		$4,542,000
	2020	annual total		$5,424,000
	2025	annual total		$6,423,675
	2030	annual total		$8,230,425
	2035	annual total		$10,157,625
	2040	annual total		$11,843,925

40-Year Present Worth Summary

Item	Cost	Total
I *Capital*		
Wellfield	$5,898,000	
South Canadian River, West Side and East Side Reservoirs	$36,000,000	
Conveyance / Transmission	$26,991,000	
Treatment / Production	$39,798,000	
Total		$108,687,000
II *O&M*		
Wellfield	$29,022,000	
OKC Treated Water Purchase	$49,349,000	
South Canadian River Reservoir O&M	$4,990,000	
South Canadian River Raw Water Conveyance	$6,476,000	
Treatment / Production	$85,380,000	
Total		$175,217,000

Notes:

Present Worth assumes n = 40 yr, annual increase in O&M cost of 3% and interest rate of 5% for an effective i = 2%

Conveyance cost estimates do not include right-of-way costs.

Table C-8
Norman Strategic Water Supply Plan
Water Supply Plan Alternative F

Item	Description	Cost	Total
Capital			
I New Wellfield	30 new wells	$ 5,748,000	
II Wellhead Land Purchase	30 acres	$ 150,000	
III New Wellfield Disinfection System	14 MGD capacity	$ 2,078,000	
IV Wellfield Transmission Network	8- to 24-inch diameter	$ 7,350,000	
V Lake Campbell	3,200 acre-ft	$ 11,664,000	
VI WTP Conveyance Pipeline Replacement	30-inch diameter	$ 6,211,000	
VII South Canadian River	50 MGD Intake capacity	$ 10,160,000	
VIII S. C. Conveyance Piping (West Side Reservoir)	50 MGD conveyance capacity	$ 3,780,000	
IX West Side Reservoir	8,400 acre-ft	$ 20,570,000	
X Norman WTP: South Canadian Treatment Train	22 MGD treatment capacity	$ 42,480,000	
			$ 110,191,000
Annual O&M			
I WTP (Existing)			
2000-2040	8.4 MGD annual average	$ 1,604,000	
III WTP Reservoir O&M and Conveyance			
2005-2040	8.4 MGD annual average	$ 318,000	
II New S.C. WTP			
2010	10.3 MGD annual average	$ 541,500	
2015	13 MGD annual average	$ 1,311,000	
2020	15.8 MGD annual average	$ 2,109,000	
2025-2040	18.4 MGD annual average	$ 2,850,000	
III South Canadian Conveyance System			
2010	annual average	$ 34,200	
2015	annual average	$ 82,800	
2020	annual average	$ 133,200	
2025-2040	annual average	$ 180,000	
IV South Canadian Reservoirs			
2010-2040	reservoir O&M	$ 210,000	
V Wellfield (Existing with expansion and new)			
2000	31 wells	$ 307,000	
2005	46 wells	$ 746,000	
2010 - 2040	61 wells	$ 1,184,000	
VI New Wellfield Disinfection System			
2005	5 MGD annual average	$ 22,500	
2010-2040	10 MGD annual average	$ 45,000	
VII OKC Treated Water Purchase			
2000	7.0 MGD	$ 4,215,750	
2005	5.0 MGD	$ 3,011,250	
2025	0.3 MGD	$ 180,675	
2030	3.3 MGD	$ 1,987,425	
2035	6.5 MGD	$ 3,914,625	
2040	9.3 MGD	$ 5,600,925	
VIII Annual O&M Summary			
2000	annual total		$ 6,126,750
2005	annual total		$ 5,701,750
2010	annual total		$ 3,936,700
2015	annual total		$ 4,754,800
2020	annual total		$ 5,603,200
2025	annual total		$ 6,361,675
2030	annual total		$ 8,168,425
2035	annual total		$ 10,095,625
2040	annual total		$ 11,781,925
40-Year Present Worth Summary			
I *Capital*			
Wellfield		$ 5,898,000	
South Canadian River and West Side Reservoir		$ 30,730,000	
Conveyance / Transmission		$ 29,005,000	
Treatment / Production		$ 44,558,000	
Total			$ 110,191,000
II *O&M*			
Wellfield		$ 29,022,000	
OKC Treated Water Purchase		$ 49,349,000	
South Canadian River Reservoir O&M		$ 4,031,000	
South Canadian River Raw Water Conveyance		$ 2,591,000	
Treatment / Production		$ 94,453,000	
Total			$ 179,446,000

Note:
Present Worth assumes n = 40 yr, annual increase in O&M cost of 3% and interest rate of 5% for an effective i = 2%
Conveyance cost estimates do not include right-of-way costs.

Appendix D
Financial Analysis

Table D-1
Norman Strategic Water Supply Plan
Capital Outlay Plan - 2000 Present Worth

PROJECT	PROJECTED COST, 2000 DOLLARS 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
New Wellfield, Land Purchase	$ 25,000	$ -	$ -	$ -	$ 75,000	$ -	$ -	$ -	$ -	$ 25,000
New Wellfield, Production Wells	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 570,000	$ 570,000	$ 570,000	$ 570,000	$ 570,000
New Wellfield, Monitoring Wells	$ 16,000	$ -	$ -	$ -	$ -	$ 16,000	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ 456,000	$ 304,000	$ 507,000	$ 608,000	$ 1,419,000	$ 1,166,000	$ 507,000	$ 558,000	$ 456,000	$ 507,000
New Wellfield, Disinfection Facility	$	$ -	$ -	$ -	$ -	$ -	$ -	$ 208,000	$ 1,247,000	$ 623,000
Terminal Reservoir, Land Purchase	$ 1,080,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ 983,000	$ 5,896,000	$ 2,948,000	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 250,000	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ 611,000	$ 3,666,000	$ 1,833,000	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ 380,000	$ 2,278,000	$ 1,138,000	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 1,590,000	$ 9,540,000	$ 4,770,000
WTP, Phase II Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 1,767,000	$ 494,000	$ 697,000	$ 1,781,000	$ 8,191,000	$ 8,366,000	$ 3,290,000	$ 5,204,000	$ 13,201,000	$ 6,495,000
									10 year total	$ 49,486,000

Table D-1
Norman Strategic Water Supply Plan
Capital Outlay Plan - 2000 Present Worth

PROJECT	PROJECTED COST, 2000 DOLLARS 2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
New Wellfield, Land Purchase	$ -	$ -	$ -	$ -	$ 25,000	$ -	$ -	$ -	$ -	$ -
New Wellfield, Production Wells	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000
New Wellfield, Monitoring Wells	$ -	$ 16,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ 456,000	$ -	$ 203,000	$ -	$ -	$ 203,000	$ -	$ -	$ -	$ -
New Wellfield, Disinfection Facility	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase II Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 646,000	$ 206,000	$ 393,000	$ 190,000	$ 215,000	$ 393,000	$ 190,000	$ 190,000	$ 190,000	$ 190,000

Table D-1
Norman Strategic Water Supply Plan
Capital Outlay Plan - 2000 Present Worth

PROJECT	PROJECTED COST, 2000 DOLLARS 2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
New Wellfield, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Production Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Monitoring Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Disinfection Facility	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ 76,000	$ 454,000	$ 227,000	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase II Expansion (10 MGD)	$ -	$ 1,590,000	$ 9,540,000	$ 4,770,000	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ -	$ 1,666,000	$ 9,994,000	$ 4,997,000	$ -	$ -	$ -	$ -	$ -	$ -

Table D-1
Norman Strategic Water Supply Plan
Capital Outlay Plan - 2000 Present Worth

PROJECT	PROJECTED COST, 2000 DOLLARS 2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
New Wellfield, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Production Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Monitoring Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Disinfection Facility	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase II Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ 1,154,000	$ 6,922,000	$ 3,461,000	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ -	$ 1,154,000	$ 6,922,000	$ 3,461,000	$ -	$ -	$ -	$ -	$ -	$ -

Table D-2
Norman Strategic Water Supply Plan
Capital Outlay Plan - Adjusted for Inflation

PROJECT	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
New Wellfield, Land Purchase	$ 25,750	$ -	$ -	$ -	$ 86,946	$ -	$ -	$ -	$ -	$ 33,598
New Wellfield, Production Wells	$ 195,700	$ 201,571	$ 207,618	$ 213,847	$ 220,262	$ 680,610	$ 701,028	$ 722,059	$ 743,721	$ 766,032
New Wellfield, Monitoring Wells	$ 16,480	$ -	$ -	$ -	$ -	$ 19,105	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ 469,680	$ 322,514	$ 554,013	$ 684,309	$ 1,645,010	$ 1,392,265	$ 623,546	$ 706,858	$ 594,977	$ 681,366
New Wellfield, Disinfection Facility	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 263,488	$ 1,627,052	$ 837,260
Terminal Reservoir, Land Purchase	$ 1,112,400	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ 1,106,375	$ 6,835,080	$ 3,520,066	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 326,193	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ 708,316	$ 4,377,396	$ 2,254,359	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ 467,352	$ 2,885,702	$ 1,484,832	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 2,014,164	$ 12,447,536	$ 6,410,481
WTP, Phase II Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 1,820,010	$ 524,085	$ 761,631	$ 2,004,531	$ 9,495,614	$ 9,989,442	$ 4,046,285	$ 6,592,272	$ 17,224,311	$ 8,728,737
									10 year total	$ 61,186,916

Table D-2
Norman Strategic Water Supply Plan
Capital Outlay Plan - Adjusted for Inflation

PROJECT	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
New Wellfield, Land Purchase	$ -	$ -	$ -	$ -	$ 38,949	$ -	$ -	$ -	$ -	$ -
New Wellfield, Production Wells	$ 263,004	$ 270,895	$ 279,021	$ 287,392	$ 296,014	$ 304,894	$ 314,041	$ 323,462	$ 333,166	$ 343,161
New Wellfield, Monitoring Wells	$ -	$ 22,812	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ 631,211	$ -	$ 298,112	$ -	$ -	$ 325,755	$ -	$ -	$ -	$ -
New Wellfield, Disinfection Facility	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase II Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ 894,215	$ 293,707	$ 577,134	$ 287,392	$ 334,963	$ 630,650	$ 314,041	$ 323,462	$ 333,166	$ 343,161

Table D-2
Norman Strategic Water Supply Plan
Capital Outlay Plan - Adjusted for Inflation

PROJECT	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
New Wellfield, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Production Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Monitoring Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Disinfection Facility	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ 145,624	$ 896,008	$ 461,444	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase II Expansion (10 MGD)	$ -	$ 3,046,604	$ 18,828,015	$ 9,696,428	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ -	$ 3,192,228	$ 19,724,024	$ 10,157,872	$ -	$ -	$ -	$ -	$ -	$ -

Table D-2
Norman Strategic Water Supply Plan
Capital Outlay Plan - Adjusted for Inflation

PROJECT	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
New Wellfield, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Production Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Monitoring Wells	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Piping	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
New Wellfield, Disinfection Facility	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Land Purchase	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Reservoir Construction	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Terminal Reservoir, Pump Station Expansion (17 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, OKC Diversion Structure	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase I WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Raw Water Conveyance, Phase II WTP Raw Water Line	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase I Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase II Expansion (10 MGD)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
WTP, Phase III Expansion (7 MGD)	$ -	$ 2,971,646	$ 18,359,465	$ 9,455,124	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	$ -	$ 2,971,646	$ 18,359,465	$ 9,455,124	$ -	$ -	$ -	$ -	$ -	$ -

Table D-3
Norman Strategic Water Supply Plan
Financial Impacts Analysis
Scenario No. 1 - Funding Sources and Debt Service Schedules

	Estimate 2001	Forecast 2002	Forecast 2003	Forecast 2004	Forecast 2005	Forecast 2006	Forecast 2007	Forecast 2008	Forecast 2009	Forecast 2010	Forecast 2011	Forecast 2012	Forecast 2013
Beginning Balance, Construction Fund	$ -	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,132,748	$ 2,988,336
Sources of Funds (a)													
OWRB Proceeds	$ -	$ -	$ -	$ -	$ 23,000,000	$ -	$ -	$ 31,000,000	$ -	$ -	$ -	$ -	$ -
SRF Loan Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9,200,000	$ -	$ -	$ 12,400,000	$ -	$ -
Revenue Bond Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,800,000	$ -	$ -	$ 18,600,000	$ -	$ -
Revenue Bond Proceeds (other)	$ 5,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,000,000	$ -	$ -
Interest on Construction Fund @ 5%	$ 79,500	$ 149,872	$ 125,223	$ 62,330	$ 352,943	$ 458,464	$ 130,494	$ 646,055	$ 857,943	$ 252,014	$ 99,041	$ 149,295	$ 134,988
Total Funds (b)	$ 5,079,500	$ 149,872	$ 125,223	$ 62,330	$ 23,352,943	$ 458,464	$ 130,494	$ 54,646,055	$ 857,943	$ 252,014	$ 34,099,041	$ 149,295	$ 134,988
Uses of Funds													
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000,000	$ -	$ -	$ 31,000,000	$ -	$ -
Total CIP Expenditures	$ 1,820,010	$ 524,085	$ 761,631	$ 2,004,531	$ 9,495,614	$ 9,989,442	$ 4,046,285	$ 6,592,272	$ 17,224,311	$ 8,728,737	$ 894,215	$ 293,707	$ 577,134
Ending Balance, Construction Fund	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,132,748	$ 2,988,336	$ 2,546,190
Payment Structure (c)													
TOTAL DEBT	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 1,501,297	$ 1,501,297	$ 1,501,297	$ 3,515,577	$ 3,515,577	$ 3,515,577	$ 4,491,081	$ 4,491,081	$ 4,491,081

Notes:
a Consistent with the construction draw-downs, financing for major projects occurs in three year increments.
b Includes interest on the construction fund and beginning balance, **first year.**
c **Debt financing assumptions are outlined as follows:** OWRB Promissory Notes assume an annual interest rate of 4.25% and an annual finance costs of .5%. After the construction period (3 yrs), 40% of the note is repaid with proceeds from an SRF loan and 60% is repaid with proceeds from a Revenue Bond. SRF loans assume 0% interest, annual finance costs of .5%, no debt service reserve, and a 20-year term. Revenue Bonds assume a 6.16% interest rate, one-time finance costs of 3.25%, a debt service of 7.39% (equal to one payment), and a 30-year term.

Table D-3
Norman Strategic Water Supply Plan
Financial Impacts Analysis
Scenario No. 1 - Funding Sources and Debt Service Schedules

	Forecast 2014	Forecast 2015	Forecast 2016	Forecast 2017	Forecast 2018	Forecast 2019	Forecast 2020	Forecast 2021	Forecast 2022	Forecast 2023	Forecast 2024	Forecast 2025	Forecast 2026	Forecast 2027
Beginning Balance, Construction Fund	$ 2,546,190	$ 2,378,923	$ 2,154,532	$ 1,615,843	$ 1,374,743	$ 1,111,931	$ 826,032	$ 515,594	$ 541,374	$ 29,071,409	$ 10,307,855	$ 411,429	$ 432,000	$ 453,600
Sources of Funds (a)														
OWRB Proceeds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 31,000,000	$ -	$ -	$ -	$ -	$ -
SRF Loan Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 12,400,000	$ -	$ -
Revenue Bond Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 18,600,000	$ -	$ -
Revenue Bond Proceeds (other)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Interest on Construction Fund @ 5%	$ 120,125	$ 110,572	$ 91,960	$ 72,941	$ 60,651	$ 47,267	$ 32,723	$ 25,780	$ 722,263	$ 960,470	$ 261,446	$ 20,571	$ 21,600	$ 22,680
Total Funds (b)	$ 120,125	$ 110,572	$ 91,960	$ 72,941	$ 60,651	$ 47,267	$ 32,723	$ 25,780	$ 31,722,263	$ 960,470	$ 261,446	$ 31,020,571	$ 21,600	$ 22,680
Uses of Funds														
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 31,000,000	$ -	$ -
Total CIP Expenditures	$ 287,392	$ 334,963	$ 630,650	$ 314,041	$ 323,462	$ 333,166	$ 343,161	$ -	$ 3,192,228	$ 19,724,024	$ 10,157,872	$ -	$ -	$ -
Ending Balance, Construction Fund	$ 2,378,923	$ 2,154,532	$ 1,615,843	$ 1,374,743	$ 1,111,931	$ 826,032	$ 515,594	$ 541,374	$ 29,071,409	$ 10,307,855	$ 411,429	$ 432,000	$ 453,600	$ 476,280
Payment Structure (c)														
TOTAL DEBT	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 5,963,581	$ 5,963,581	$ 5,963,581	$ 6,693,807	$ 6,693,807	$ 6,693,807

Notes:
a Consistent with the construction draw-downs, financing for major projects occurs in three year increments.
b Includes interest on the construction fund and beginning balance, **first year.**
c **Debt financing assumptions are outlined as follows:** OWRB Promissory Notes assume an annual interest rate of 4.25% and annual finance costs of .5%. After the construction period (3 yrs), 40% of the note is repaid with proceeds from an SRF loan and 60% is repaid with proceeds from a Revenue Bond. SRF loans assume 0% interest, annual finance costs of .5%, no debt service reserve, and a 20-year term. Revenue Bonds assume a 6.16% interest rate, one-time finance costs of 3.25%, a debt service of 7.39% (equal to one payment), and a 30-year term.

Table D-3
Norman Strategic Water Supply Plan
Financial Impacts Analysis
Scenario No. 1 - Funding Sources and Debt Service Schedules

	Forecast 2028	Forecast 2029	Forecast 2030	Forecast 2031	Forecast 2032	Forecast 2033	Forecast 2034	Forecast 2035	Forecast 2036	Forecast 2037	Forecast 2038	Forecast 2039	Forecast 2040
Beginning Balance, Construction Fund	$ 476,280	$ 500,094	$ 525,099	$ 551,354	$ 578,922	$ 27,286,931	$ 9,832,827	$ 632,966	$ 664,614	$ 697,845	$ 732,737	$ 769,374	$ 807,843
Sources of Funds (a)													
OWRB Proceeds	$ -	$ -	$ -	$ -	$ 29,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SRF Loan Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 11,600,000	$ -	$ -	$ -	$ -	$ -
Revenue Bond Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 17,400,000	$ -	$ -	$ -	$ -	$ -
Revenue Bond Proceeds (other)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Interest on Construction Fund @ 5%	$ 23,814	$ 25,005	$ 26,255	$ 27,568	$ 679,655	$ 905,360	$ 255,263	$ 31,648	$ 33,231	$ 34,892	$ 36,637	$ 38,469	$ 40,392
Total Funds (b)	$ 23,814	$ 25,005	$ 26,255	$ 27,568	$ 29,679,655	$ 905,360	$ 255,263	$ 29,031,648	$ 33,231	$ 34,892	$ 36,637	$ 38,469	$ 40,392
Uses of Funds													
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 29,000,000	$ -	$ -	$ -	$ -	$ -
Total CIP Expenditures	$ -	$ -	$ -	$ -	$ 2,971,646	$ 18,359,465	$ 9,455,124	$ -	$ -	$ -	$ -	$ -	$ -
Ending Balance, Construction Fund	$ 500,094	$ 525,099	$ 551,354	$ 578,922	$ 27,286,931	$ 9,832,827	$ 632,966	$ 664,614	$ 697,845	$ 732,737	$ 769,374	$ 807,843	$ 848,235
Payment Structure (c)													
TOTAL DEBT	$ 6,187,807	$ 6,187,807	$ 5,779,009	$ 5,097,009	$ 6,474,509	$ 6,474,509	$ 6,474,509	$ 7,157,623	$ 7,157,623	$ 6,029,343	$ 6,029,343	$ 6,029,343	$ 4,263,340

Notes:
a Consistent with the construction draw-downs, financing for major projects occurs in three year increments.
b Includes interest on the construction fund and beginning balance, **first year.**
c **Debt financing assumptions are outlined as follows:** OWRB Promissory Notes assume an annual interest rate of 4.25% and annual finance costs of .5%. After the construction period (3 yrs), 40% of the note is repaid with proceeds from an SRF loan and 60% is repaid with proceeds from a Revenue Bond. SRF loans assume 0% interest, annual finance costs of .5%, no debt service reserve, and a 20-year term. Revenue Bonds assume a 6.16% interest rate, one-time finance costs of 3.25%, a debt service of 7.39% (equal to one payment), and a 30-year term.

Table D-4
Norman Strategic Water Supply Plan
Financial Impacts Analysis
Scenario No. 2 - Funding Sources and Debt Service Schedules

	Estimate 2001	Forecast 2002	Forecast 2003	Forecast 2004	Forecast 2005	Forecast 2006	Forecast 2007	Forecast 2008	Forecast 2009	Forecast 2010	Forecast 2011	Forecast 2012	Forecast 2013
Beginning Balance, Construction Fund	$ -	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,632,748	$ 4,263,336
Sources of Funds (a)													
OWRB Proceeds	$ -	$ -	$ -	$ -	$ 23,000,000	$ -	$ -	$ 31,000,000	$ -	$ -	$ -	$ -	$ -
SRF Loan Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9,200,000	$ -	$ -	$ 12,400,000	$ -	$ -
Revenue Bond Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 13,800,000	$ -	$ -	$ 18,600,000	$ -	$ -
Revenue Bond Proceeds	$ 5,000,000	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,000,000	$ -	$ -
Cash (Current revenue-financing)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 500,000	$ 750,000	$ 1,000,000
Interest on Construction Fund @ 5%	$ 79,500	$ 149,872	$ 125,223	$ 62,330	$ 352,943	$ 458,464	$ 130,494	$ 646,055	$ 857,943	$ 252,014	$ 99,041	$ 174,295	$ 198,738
Total Funds (b)	$ 5,079,500	$ 149,872	$ 125,223	$ 62,330	$ 23,352,943	$ 458,464	$ 130,494	$ 54,646,055	$ 857,943	$ 252,014	$ 34,599,041	$ 924,295	$ 1,198,738
Uses of Funds													
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 23,000,000	$ -	$ -	$ 31,000,000	$ -	$ -
Total CIP Expenditures	$ 1,820,010	$ 524,085	$ 761,631	$ 2,004,531	$ 9,495,614	$ 9,989,442	$ 4,046,285	$ 6,592,272	$ 17,224,311	$ 8,728,737	$ 894,215	$ 293,707	$ 577,134
Ending Balance, Construction Fund	$ 3,259,490	$ 2,885,277	$ 2,248,870	$ 306,668	$ 14,163,998	$ 4,633,020	$ 717,229	$ 25,771,013	$ 9,404,645	$ 927,922	$ 3,632,748	$ 4,263,336	$ 4,884,940
Payment Structure (c)													
2001 Revenue	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797
2005 OWRB					$ 1,092,500	$ 1,092,500	$ 1,092,500						
2008 OWRB								$ 1,472,500	$ 1,472,500	$ 1,472,500			
2008 SRF								$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000
2008 Revenue								$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280
2011 SRF											$ 682,000	$ 682,000	$ 682,000
2011 Revenue											$ 1,766,004	$ 1,766,004	$ 1,766,004
TOTAL DEBT	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 1,501,297	$ 1,501,297	$ 1,501,297	$ 3,515,577	$ 3,515,577	$ 3,515,577	$ 4,491,081	$ 4,491,081	$ 4,491,081

Notes:
a Consistent with the construction draw-downs, financing for major projects occurs in three year increments.
b Includes interest on the construction fund and beginning balance, **first year.**
c **Debt financing assumptions are outlined as follows:** OWRB Promissory Notes assume an annual interest rate of 4.25% and annual finance costs of .5%. After the construction period (3 yrs), 40% of the note is repaid with proceeds from an SRF loan and 60% is repaid with proceeds from a Revenue Bond. SRF loans assume 0% interest, annual finance costs of .5%, no debt service reserve, and a 20-year term. Revenue Bonds assume a 6.16% interest rate, one-time finance costs of 3.25%, a debt service of 7.39% (equal to one payment), and a 30-year term.

Table D-4
Norman Strategic Water Supply Plan
Financial Impacts Analysis
Scenario No. 2 - Funding Sources and Debt Service Schedules

	Forecast 2014	Forecast 2015	Forecast 2016	Forecast 2017	Forecast 2018	Forecast 2019	Forecast 2020	Forecast 2021	Forecast 2022	Forecast 2023	Forecast 2024	Forecast 2025	Forecast 2026	Forecast 2027
Beginning Balance, Construction Fund	$ 4,884,940	$ 6,334,610	$ 8,308,003	$ 10,076,988	$ 12,258,945	$ 14,540,343	$ 17,425,865	$ 20,445,418	$ 23,967,689	$ 24,394,040	$ 7,896,617	$ 379,629	$ 2,898,610	$ 5,543,540
Sources of Funds (a)														
OWRB Proceeds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SRF Loan Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Revenue Bond Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Revenue Bond Proceeds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cash (Current revenue-financing)	$ 1,500,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,000,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000
Interest on Construction Fund @ 5%	$ 237,062	$ 308,356	$ 399,634	$ 495,998	$ 604,861	$ 718,688	$ 862,714	$ 1,022,271	$ 1,118,579	$ 726,601	$ 140,884	$ 18,981	$ 144,930	$ 277,177
Total Funds (b)	$ 1,737,062	$ 2,308,356	$ 2,399,634	$ 2,495,998	$ 2,604,861	$ 3,218,688	$ 3,362,714	$ 3,522,271	$ 3,618,579	$ 3,226,601	$ 2,640,884	$ 2,518,981	$ 2,644,930	$ 2,777,177
Uses of Funds														
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total CIP Expenditures	$ 287,392	$ 334,963	$ 630,650	$ 314,041	$ 323,462	$ 333,166	$ 343,161	$ -	$ 3,192,228	$ 19,724,024	$ 10,157,872	$ -	$ -	$ -
Ending Balance, Construction Fund	$ 6,334,610	$ 8,308,003	$ 10,076,988	$ 12,258,945	$ 14,540,343	$ 17,425,865	$ 20,445,418	$ 23,967,689	$ 24,394,040	$ 7,896,617	$ 379,629	$ 2,898,610	$ 5,543,540	$ 8,320,717
Payment Structure (c)														
2001 Revenue	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797	$ 408,797
2005 OWRB														
2008 OWRB														
2008 SRF	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000	$ 506,000
2008 Revenue	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280
2011 SRF	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000	$ 682,000
2011 Revenue	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004
TOTAL DEBT	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081	$ 4,491,081

Notes:

a Consistent with the construction draw-downs, financing for major projects occurs in three year increments.

b Includes interest on the construction fund and beginning balance, **first year.**

c **Debt financing assumptions are outlined as follows:** OWRB Promissory Notes assume an annual interest rate of 4.25% and annual finance costs of .5%. After the construction period (3 yrs), 40% of the note is repaid with proceeds from an SRF loan and 60% is repaid with proceeds from a Revenue Bond. SRF loans assume 0% interest, annual finance costs of .5%, no debt service reserve, and a 20-year term. Revenue Bonds assume a 6.16% interest rate, one-time finance costs of 3.25%, a debt service of 7.39% (equal to one payment), and a 30-year term.

Table D-4
Norman Strategic Water Supply Plan
Financial Impacts Analysis
Scenario No. 2 - Funding Sources and Debt Service Schedules

	Forecast 2028	Forecast 2029	Forecast 2030	Forecast 2031	Forecast 2032	Forecast 2033	Forecast 2034	Forecast 2035	Forecast 2036	Forecast 2037	Forecast 2038	Forecast 2039	Forecast 2040
Beginning Balance, Construction Fund	$ 8,320,717	$ 11,236,753	$ 14,298,591	$ 17,513,521	$ 20,889,197	$ 21,387,720	$ 6,638,655	$ 279,086	$ 293,040	$ 307,692	$ 323,077	$ 339,231	$ 356,193
Sources of Funds (a)													
OWRB Proceeds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
SRF Loan Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Revenue Bond Proceeds (OWRB repay)	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Revenue Bond Proceeds	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cash (Current revenue-financing)	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 2,500,000	$ 3,000,000	$ 3,000,000	$ -	$ -	$ -	$ -	$ -	$ -
Interest on Construction Fund @ 5%	$ 416,036	$ 561,838	$ 714,930	$ 875,676	$ 970,169	$ 610,399	$ 95,555	$ 13,954	$ 14,652	$ 15,385	$ 16,154	$ 16,962	$ 17,810
Total Funds (b)	$ 2,916,036	$ 3,061,838	$ 3,214,930	$ 3,375,676	$ 3,470,169	$ 3,610,399	$ 3,095,555	$ 13,954	$ 14,652	$ 15,385	$ 16,154	$ 16,962	$ 17,810
Uses of Funds													
OWRB Repayment	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total CIP Expenditures	$ -	$ -	$ -	$ -	$ 2,971,646	$ 18,359,465	$ 9,455,124	$ -	$ -	$ -	$ -	$ -	$ -
Ending Balance, Construction Fund	$ 11,236,753	$ 14,298,591	$ 17,513,521	$ 20,889,197	$ 21,387,720	$ 6,638,655	$ 279,086	$ 293,040	$ 307,692	$ 323,077	$ 339,231	$ 356,193	$ 374,003
Payment Structure (c)													
2001 Revenue	$ 408,797	$ 408,797											
2005 OWRB													
2008 OWRB													
2008 SRF													
2008 Revenue	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280	$ 1,128,280				
2011 SRF	$ 682,000	$ 682,000	$ 682,000										
2011 Revenue	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ 1,766,004	
TOTAL DEBT	$ 3,985,081	$ 3,985,081	$ 3,576,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 2,894,284	$ 1,766,004	$ 1,766,004	$ 1,766,004	$ -

Notes:
a Consistent with the construction draw-downs, financing for major projects occurs in three year increments.
b Includes interest on the construction fund and beginning balance, **first year.**
c **Debt financing assumptions are outlined as follows:** OWRB Promissory Notes assume an annual interest rate of 4.25% and annual finance costs of .5%. After the construction period (3 yrs), 40% of the note is repaid with proceeds from an SRF loan and 60% is repaid with proceeds from a Revenue Bond. SRF loans assume 0% interest, annual finance costs of .5%, no debt service reserve, and a 20-year term. Revenue Bonds assume a 6.16% interest rate, one-time finance costs of 3.25%, a debt service of 7.39% (equal to one payment), and a 30-year term.

Appendix E
Acronyms and Abbreviations

Acronyms and Abbreviations

ac-ft	acre-feet
AR	Arsenic Rule
BAT	best available technology
BG	billion gallons
BOD	biochemical oxygen demand
$CaCO_3$	calcium carbonate
City	City of Norman
COE	U.S. Army Corps of Engineers
COMCD	Central Oklahoma Master Conservancy District
CT	disinfectant residual concentration times disinfectant contact time
D/DBP	Disinfectants/Disinfection Byproducts Rule
DBP	disinfectant byproducts
EPA	U.S. Environmental Protection Agency
ESWTR	Enhanced Surface Water Treatment Rule
ft	foot
gpcd	gallons per capita per day
gpd/ft	gallons per day per foot
gpd/ft^2	gallons per day per square foot
gpd/ft^3	gallons per day per cubic foot
GWA	Garber-Wellington Aquifer
GWR	Groundwater Rule
HAA5	haloacetic acids
hp	horsepower
IESWTR	Interim Enhanced Surface Water Treatment Rule
IOC	inorganic chemicals
IPDWR	Interim Primary Drinking Water Regulations

LT1FBR	Long-Term 1 Enhanced Surface Water Treatment and Filter Backwash Rule
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
MCL	Maximum Contaminant Level
MCLG	maximum contaminant level goals
MG	million gallons
mg/L	milligrams per liter
mgd	million gallons per day
MRDL	maximum residual disinfectant levels
MRDLG	maximum residual disinfectant level goals
mrem/yr	measure of the dose effect of radiation
NIPDWR	National Interim Primary Drinking Water Regulations
NISDWR	National Interim Secondary Drinking Water Regulations
nm	nanometer
NPDWR	National Primary Drinking Water Regulations
NTU	nephelometric turbidity units
OCWUT	Oklahoma City Water Utility Trust
ODEQ	Oklahoma Department of Environmental Quality
OKC	City of Oklahoma City
PAC	powder activated carbon
pCi/L	picocurie per liter
ppb	parts per billion
RMCL	recommended maximum contaminant level
SDWA	Safe Drinking Water Act
SOC	synthetic organic chemicals
Stage 1 D/DBPR	Stage 1 Disinfectants/Disinfection Byproducts Rule
Stage 2 D/DBPR	Stage 2 Disinfectants/Disinfection Byproducts Rule
SUVA	specific ultraviolet absorbance
SWTR	Surface Water Treatment Rule
TCR	Total Coliform Rule

TDS	total dissolved solids
TOC	total organic carbon
TTHM	total trihalomethanes
USGS	U.S. Geological Survey
VOC	volatile organic chemicals
WTP	Norman Water Treatment Plant
WWTP	Norman Wastewater Treatment Plant
μg/L	micrograms per liter